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AICE* SURVEY OF USSR AIR POLLUTION LITERATURE

Volume II

EFFECTS AND SYMPTOMS OF AIR POLLUTES ON VEGETATION; RESISTANCE AND SUSCEPTIBILITY OF DIFFERENT PLANT SPECIES IN VARIOUS HABITATS, IN RELATION TO PLANT UTILIZATION FOR SHELTER BELTS AND AS BIOLOGICAL INDICATORS

Edited By

M. Y. Nuttonson

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USSR literature on air pollution
conducted by the
Air Pollution Section
AMERICAN INSTITUTE OF CROP ECOLOGY

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A compilation of reports of investigations dealing with a number of aspects of the relationship of air pollution and vegetation. A number of these studies are concerned with susceptibility of different plant species to various phytotoxic pollutants in different parts of the country. Some of these are; the effect of industrial atmospheric pollutants on various plant species grown as ornamentals and for sanitary-protection purposes, the adverse effects of pollutants on indigenous and introduced plant species. Other papers deal with the need to eliminate contaminants from the atmosphere and to control air quality. Among some of the additional subjects discussed are those of the effect of green plantings on the sanitary conditions of populated areas. Attention is also given to ascertaining of some physiological responses of various plants to specific air pollutants and their time-concentrations.

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PREFACE

Contamination of the natural environment constitutes a major problem in all industrial regions of the Union of Soviet Socialist Republics (USSR). The country's industry and transport are continually bringing about massive qualitative changes in the habitat of man and vegetation through an ever increasing pollution of air, soil, and streams. In recent years there has been a greater awareness of the immense problems of air and water pollution on the part of the urban and rural administrative agencies as well as on the part of various research institutes of the USSR. There is a mounting demand there to maintain a high quality physical environment. Protective measures against the pollution threat are gradually taking shape. Much relevant air pollution research data are being developed and are apparently put to good use in different parts of this vast and diverse country.

Reports of investigations brought together in this volume deal with a number of aspects of the relationship of air pollution and vegetation. A considerable number of these investigations have been conducted in various *industrial* regions of the USSR, regions that are geographically far apart from each other and subject to distinctly different natural and man-made environmental conditions.

Many of these investigations relate to the urban and rural areas particularly affected by air pollution and situated in widely separated industrial regions, the three most important of which are:

1. The Ural Oblast' of the Russian Soviet Federated Socialist Republic (RSFSR), which occupies a most important position in the industrial economy of the country. It lies in the interior of the USSR midway between its European and Asian parts, that is, between the country's older, highly developed industrial regions in the west and its newer gigantic industrial regions of the east;

2. The Don Basin, which is situated over 1,000 miles west of the Urals and lies in the Ukraininian SSR, the country's leading industrial republic;

3. The Kuznetsk Basin of the RSFSR, which lies in central Siberia, is more than 1,000 miles east of the Urals and constitutes the country's most important eastern center for heavy industry.

A number of investigations dealt with in this volume relate to some of the other industrial regions of the USSR. These include:

The Moscow Region, a most highly developed industrial region of the central part of RSFSR;

The Azerbaizhan SSR, whose Apsheron Peninsula is the richest oil region of the country, borders on the Caspian Sea and lies in the eastern section of Transcaucasia;

The Kazakh SSR, located deep in the Eurasian continent, has rich deposits of oil and coal and many metallurgical industries. Its vast land area makes it the second largest republic of the country, after the RSFSR.

The problem of selecting suitable plants for new environmental conditions -- whether natural or man-made -- has challenged man throughout the centuries of his migration. Selection of plants for introduction and establishment in a new environment may be a rather simple hit-and-miss undertaking, or it may become a painstaking process requiring a knowledge of plant responses to such potent factors of the physical environment as photoperiod, light intensity, temperature, humidity, soil moisture, and soil fertility. It is rather widely accepted now that air pollution, wherever it occurs, must be taken into account as another highly potent factor in the physical environment of plants. The nature of air pollution has to be considered in the assessment of the environmental conditions prevailing in a given area in relation to the overall problem of plant selection and plant adaptation. A plant, irrespective of its genetic potentialities and elasticity of adaptation to environmental conditions, responds to the various stresses of its environment. These include the stresses of air pollution together with all the other potent factors of the atmosphere as well as of soil and those of the biological environment of a plant, notably, pests and diseases, and the quality of management or abuse by man.

As will be seen from the data of the papers presented in this volume a considerable number of studies are being conducted in the USSR in reference to susceptibility or resistance of different plant species and varieties to various phytotoxic air pollutants in different parts of the country.

It must be borne in mind that the data presented in this volume relate to many diverse environments in a vast land area; that the USSR extends for about 7,000 miles from west to east and 3,000 miles from north to south; and that the country covers a wide range of climatic and soil conditions throughout much of its north-south and west-east extent. In this connection, a brief outline of the very general natural features of the USSR may be desirable. Lowlands and plains dominate the landscape of the major portion of the country. Its landscape can be roughly described as one consisting of broad latitudinal climate-vegetation-soil belts of the lowlands and plains and of narrow, vertical climate-vegetation zones of the highlands and mountains. Each of the broad latitudinal belts is distinct from the other in the major features of its climate, vegetation, and soils, though within each latitudinal belt there is a decrease in the annual precipitation as one proceeds from west to east. The latitudinal belts include the nearly barren and treeless tundra in the extreme north, where the winters are severe, the summers, short and cool, and where precipitation is very limited. There follow the belts of the taiga or coniferous forests, mixed forests, woodlands, forest prairie or forest steppe, the steppe, and the semi-desert. Finally in the extreme south, east of Caspian Sea, there are the dry deserts, hot in summer and cold in winter, and, along the southern reaches of the Black Sea in Transcaucasia, there is a relatively limited area, humid and more or less subtropical, which is subject to mild winters, hot summers, and heavy precipitation.

A considerable number of surveys and studies presented in this volume deal with the effect of industrial atmospheric pollutants on various plant species grown as ornamentals and for sanitary-protection purposes in different cities and localities at various distances from industrial sources, and situated differently in respect to their directional position from specific pollutant sources. The adverse effects of air pollution on some of the indigenous and introduced plant species -- effects often leading to complete plant destruction, such as for example, the death of ornamental plantings in urban parks and gardens and the death of forest plantings -- are described in some of the studies. Susceptibilities to specific phytotoxic air pollutants and injury symptoms in different species, ecotypes, and varieties are also discussed.

A number of papers bring out the fact that the response to air pollution differs with the plant species as well as with the ecotypes and varieties within a species and that the growth stage of the plant, notably the age of the leaf, is an important factor in determining its sensitivity to air pollutants. Other papers deal with the need to eliminate contaminants from the atmosphere and with the necessity to control air quality for the protection of man and vegetation. Among some of the additional subjects discussed in the papers are those of the effect of green plantings on the sanitary conditions of populated areas; procedures for planting sanitary-protective green belts in areas of industrial enterprises; and the establishment of verdant, protective plantings in industrial cities and in their surroundings. Much attention is given in quite a few of the papers to the resistance of various plants to different gases and to smoke, to some of the environmental conditions and physiological indices in relation to smoke and gas resistance of plants, and to the problem of plant selection for resistance to smoke and gas pollution.

The data of several studies and surveys presented in this volume deal with the ascertaining of some physiological responses of various plants to specific air pollutants and their time-concentrations. On the basis of experimental plot tests and field observations the genetic susceptibility or resistance of certain plant species, ecotypes and varieties have been determined in a number of areas. The use of the resistant plants in industrial regions as shelter belt plantings around residential areas and in urban parks, gardens, and street plantings appears to be a highly challenging approach that merits consideration. The same is true (a) in reference to rural areas subject to air pollution where shelter belt plantings are used as a means of protecting farm crops, forests, and other vegetation, and (b) in reference to certain cultural practices that appear to be conducive to a lessening of plant sensitivity to phytotoxic air pollutants.

Some of the plant material identified in these studies as being particularly sensitive to one or more pollutants merit consideration as potential biological indicators that could possibly be utilized as monitors for air pollution levels in a given area.

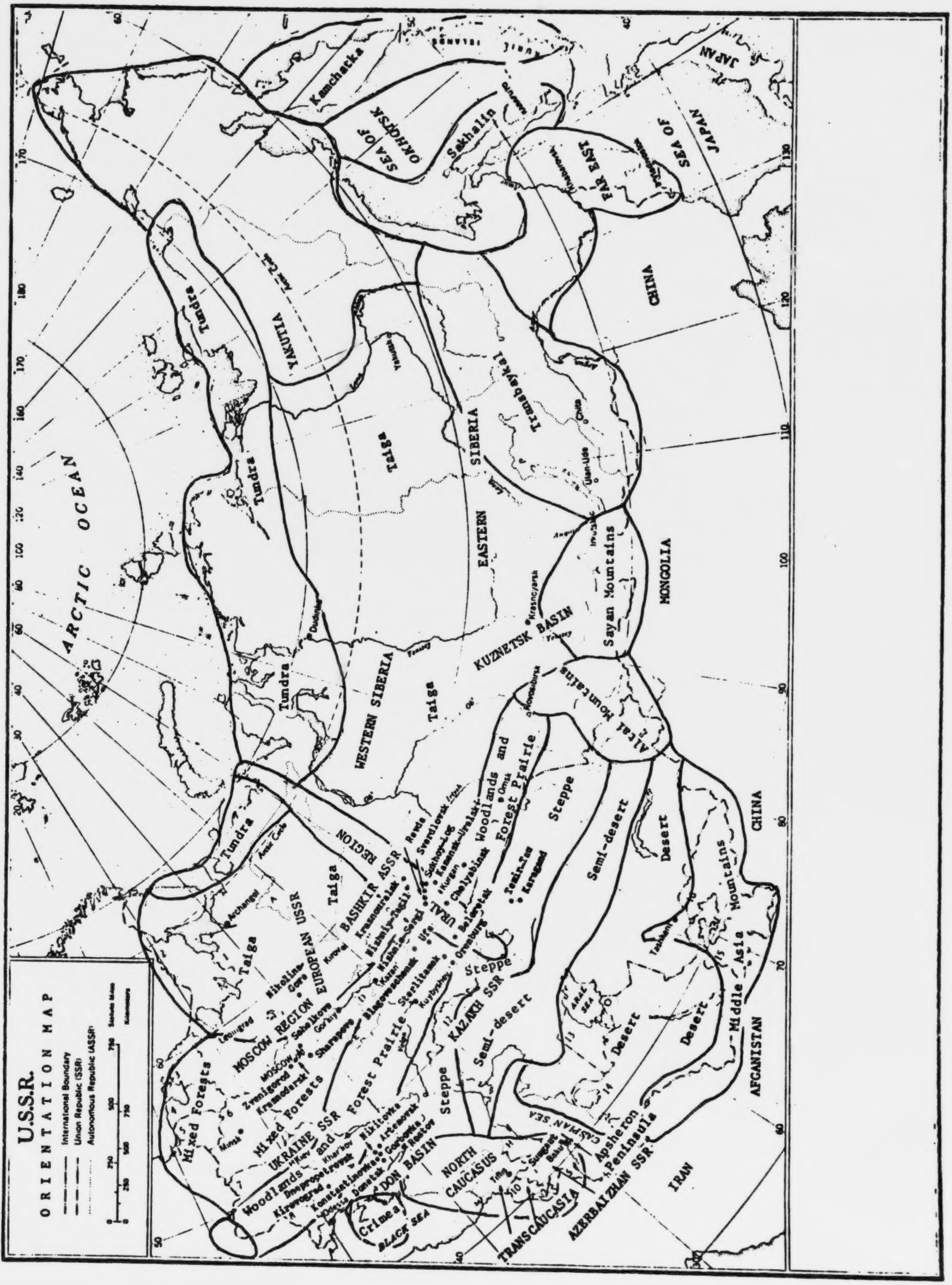
It is hoped that the papers selected for presentation in this volume will permit an assessment of some of the USSR studies dealing with the manifold interrelationships of air pollution and vegetation. There is a possibility that the usefulness of such studies would be greatly increased if supplementary detailed information could be assembled and analyzed concerning the specific environmental conditions under which each set of the data reported were developed. Such information, properly organized and analyzed, would permit a more precise identification of specific environmental responses of a given species or ecotype or variety grown in a given area under specific pollutant and time-concentration relations. It would also permit a clearer visualization of comparable climate and soil conditions in North America.

Clonal material (rooted cuttings or grafts) of specific susceptibility or specific resistance could then be introduced for field tests. The desired procedure, it is believed, should be to conduct these tests, at least at first, under environmental conditions similar to those of source areas of the introduced plant material. This may facilitate the verification of plant responses and plant adaptability and may also make possible the utilization of some of the USSR plant material under similar ecological conditions in North America.

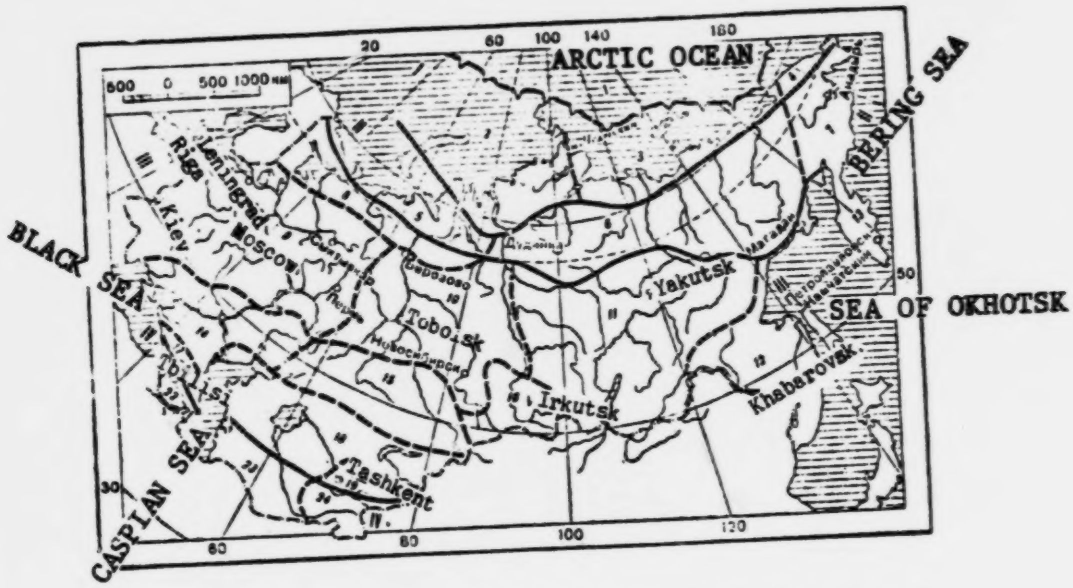
As the editor of this volume I wish to thank my co-workers in the Air Pollution Section of the Institute for their valuable assistance. Special thanks are due to Dr. M. Hoseh, who as the principal translator rendered valuable service in connection with many phases of this survey.

M. Y. Nuttonson

Silver Spring, Maryland
September 1969


U.S.S.R.
ORIENTATION MAP
International Boundary
Union Republic (SSR)
Autonomous Republic (ASSR)
ARCTIC OCEAN
Tundra
Taiga
Mixed Forests
MOSCOW REGION
EUROPEAN USSR
BASHKIR ASSR
URAL REGION
UKRAINE SSR
Woodlands and Forest Prairie
Mixed Forests
DON BASIN
Crimea
BLACK SEA
NORTH CAUCASUS
TRANSCAUCASIA
AZERBAIZHAN SSR
Apsheron Peninsula
CASPIAN SEA
IRAN
AFGANISTAN
Middle Asia Mountains
Desert
Semi-desert
Steppe
KAZAKH SSR
CHINA
Altai Mountains
Sayan Mountains
MONGOLIA
KUZNETSK BASIN
WESTERN SIBERIA
EASTERN SIBERIA
Transbaykal
YAKUTIA
FAR EAST
SEA OF JAPAN
JAPAN
Sakhalin
SEA OF OKHOTSK
Kamchatka
Leningrad
Moscow
Minsk
Kiev
Khar'kov
Archangel
Dudinka
Kazan'
Ufa
Sverdlovsk
Chelyabinsk
Orenburg
Omsk
Novosibirsk
Krasnoyarsk
Irkutsk
Ulan-Ude
Chita
Karaganda
Tashkent

CLIMATIC ZONES AND REGIONS* OF THE USSR


ARCTIC OCEAN
BERING SEA
BLACK SEA
SEA OF OKHOTSK
CASPIAN SEA
Riga
Leningrad
Moscow
Kiev
Tobolsk
Yakutsk
Irkutsk
Khabarovsk
Tashkent
Tbilisi
500 0 500 1000 km
20
60
100
140
180
50
30
60
80
100
120

Zones: I-arctic, II-subarctic, III-temperate, IV-subtropical
Regions: 1-polar, 2-Atlantic, 3-East Siberian, 4-Pacific, 5-Atlantic, 6-Siberian, 7-Pacific, 8-Atlantic-arctic, 9-Atlantic-continental forests, 10-continental forests West Siberian, 11-continental forests East Siberian, 12-monsoon forests, 13-Pacific forests, 14-Atlantic-continental steppe, 15-continental steppe West Siberian, 16-mountainous Altay and Sayan, 17-mountainous Northern Caucasus, 18-continental desert Central Asian, 19-mountainous Tyan-Shan, 20-western Transcaucasian, 21-eastern Transcaucasian, 22-mountainous Transcaucasian highlands, 23-desert south-Turanian, 24-mountainous Pamir-Alay

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* After B. P. Alisov

PURIFICATION OF ATMOSPHERIC AIR OF CONTAMINANTS FROM INDUSTRIAL DISCHARGES

V. V. Oparin
Central Ural Sovnarkhoz.

From Akad. Nauk SSSR. Ural. Filial. Komis. po Okhrane Prirody. Rastitel'nost' i promyshlennye zagryazneniya. Okhrana prirody na Urale. V (Sverdlovsk, 1966) p. 7-10.

For a long time the means for purification of the atmosphere were of a narrow compartmentalized nature and were concerned only with a partial prevention of pollution from specific enterprises. Significant work on an overall solution of the problem of purification of atmospheric air in the Ural industrial areas and cities was carried out in 1960-1965 by the Central Ural Sovnarkhoz. A number of concrete problems were solved, such as ending air pollution with the introduction of a more orderly and rational approach to the operation of purification installations in industrial enterprises.

The most important of the problems were: 1) working out an overall program and determining technical guidelines for the protection of the surrounding air; 2) methods of purification of discharges; 3) preparation of budgetary analyses; 4) construction of purification installations; 5) the organizing of a correct and effective utilization of the constructed installations, including their maintenance; the providing of work crews, and control of their performance; 6) extraction and utilization of valuable products contained in the discharges; 7) the securing of communal involvement in the program of protecting the atmosphere of populated localities.

The program of basic steps toward sanitation of the surrounding air during 1960-1965 included the construction of new and the updating of existing purification installations, improvement of their utilization, organization of research in the field of purification of atmosphere from industrial discharges, and utilization of valuable products in them.

Simultaneously, attention was paid to the fact that in adopting new technological processes in some branches of industry, no provisions were made for purification of wastes. In particular, there remain unsolved the problems of more effective purification of industrial wastes in the production of nickel, and of the trapping of non-concentrated sulfur dioxide in the exhausts generally, and specifically in the exhaust gases from roasters, reverberatory furnaces, and converters in copper smelters, from plants producing synthetic fibers, or synthetic alcohol, from agglomeration plants, and from enterprises of the building materials industry.

The Sovnarkhoz proposed the construction of 70 purification installations in 53 enterprises in its economic jurisdiction, with a total budgetary cost of 49.4 million rubles. By 1964---26 installations were built and put in operation, and 37.1 million rubles were committed, which represents 75.5% of the total required investment.

In the overall execution of the purification program throughout the region the following industries fell short of the goal: building materials, machine tools, ferrous metallurgy, chemical, light industry, and the food industry.

The non-ferrous metallurgy enterprises have done much to stop air pollution and to reduce the discharge of valuable products into the air. Of an estimated cost of 33.5 million rubles they have committed 26.8 million rubles.

The purification of the atmosphere in industrial areas is carried out in the following principal directions: 1) construction of dust catchers and gas utilization shops; 2) change in technological processes and the closing of certain industrial plants; 3) establishment of protective belts of verdant plantings around industrial plants and populated localities; 4) removal of places of habitation and various institutions from proximity to sources of pollution. Some of the measures carried out to-date and their effectiveness are tabulated. A series of enterprises were dismantled because of their strong pollution of the atmosphere and the inadvisability of providing them with devices to purify the exhaust.

The means adopted at the Nizhnie Sergi metallurgical plant are an example of an overall solution of air purification. This city is located in a picturesque resort area known for a long time and a favorite place of recreation for the workers in the Urals. However, its natural beauty was marred by the smoke and soot of the plant. The city, located in a valley, was at all times shrouded in fog and smoke. The inhabitants complained that particles of coal and soot from the plant boilers could be found even in the hearts of cabbage heads grown in a garden. In recent years blast furnaces were discontinued in the metallurgical plant, which stopped the discharge of large volumes of ore dust and furnace throat gases. Two boilers in the plant were equipped with ash catchers which in turn reduced the volume of ash in the waste from the power station. Two open hearth furnaces and one holding furnace were switched from generator gas to oil which permitted discontinuance of 9 gas generators consuming approximately 6000 tons of coal per month.

From 15 January 1964 the plant and the city were joined to the electric supply system of 'Sverdlovenergo,' which permitted the discontinuation and the placing in reserve of two boilers of the generator station, thereby reducing by more than half the consumption of coal and the pollution of the atmosphere by the industrial boiler discharges.

According to the city sanitation and epidemiological station of Nizknie Sergi, when the ash content of the power station fuel is 11%, the discharge carries 80% of the ash and 3% remains in the unburned residue. The flyash from the boilers amounts to 12.1% or 10 tons per day. At the present the plant is considering switching the open hearth furnaces to oil, which will permit the use of the power generating station, which at the present time constitutes the main source of city air pollution to be discontinued. In 1963, with the initiation of the heat-distributing system SUGRES-Sverdlovsk, 47 house-heating stations of the city having no ash-catching devices were closed down. All together the city has a total of approximately 800 boiler stations discharging 120,000 tons of ash and dust annually. Therefore, it is easy to see the importance of a centralized heat distribution system.

Measures undertaken to carry out the overall sanitation of the surrounding air

Enterprise	Adopted Means	Effectiveness
Nizhniy Tagil cement mill	Electrofilters were mounted on rotary kilns and coal drying drums	Dust discharge into the air was reduced from 600 to 90 tons/day
Uralvagonzavod	Wet scrubbers and a 140 m. pipe installed behind the boilers of the power generating plant	The total discharge of ash into the air was reduced from 800 to 100 tons/day. In the surroundings of the settlement the concentration of flyash and sulfur dioxide were reduced to permissible limits (0.5 mg./m^3), when there are no discharges from the NTMK (Nizhniy Tagil Metallurgical Combine)
Kuybyshev plant	Operation of the boiler unit changed to blast furnace gas	Discharge of dust reduced
Asbofabrika No. 3 (Asbestos plant no. 3 of the Soyus-asbestcombine)	Dust chamber and electrofilters installed in the concentration unit	Dust pollution of the air greatly reduced
Polevskoy cryolite plant	Fluorine-retaining unit installed in the cryolite shop	Concentration of fluorine in the city of Polevskoy was reduced 3-4 times; however, it still exceeds the permissible limits
Pervoural'sk potassium dichromate plant	Gas washers installed to clean the gases free of hexavalent chromium. Changes in technology; open evaporators change to closed vacuum evaporators	Total discharge of hexavalent chromium reduced 10-fold and consequently its concentration in the air in up to 2 km. radius was reduced accordingly
Kirograd copper smelter	A 140 m. pipe installed for discharging gases from the metallurgical unit	Concentration of sulfur dioxide and dust greatly reduced. Plans are laid for utilization of the sulfur dioxide
Krasnogorsk generating plant	Wet scrubbers installed on 13 boilers and a 150 m. smokestack built	
Central Ural copper smelter	In 1963 started a sulfuric acid plant. In 1964 installed the second stage of the sulfuric acid plant utilizing converter gases	Utilization of sulfuric anhydride yielded additional 145,000 tons of sulfuric acid
Verkh-Neyvinsk Zavod Vtortsvetmet (Smelter for secondary non-ferrous metals	Gases from water jacketed furnaces are purified. A 3-step purification with bag filters was installed	

Secondary power resources are used in the central heat supply in other cities as well. As time goes on, the centralized heat supply will increase and will include residential areas of such cities as Nizgniy Tagil, Sukhoy Log, and Kamensk-Ural'skiy.

Extensive work on the purification of air of the city Nizhniy Tagil is scheduled for 1964-1966. The total cost of the required installations will be 15 million rubles. The required work and installations include: purification of the gases from open hearth furnaces No. 1 and 2, and the installation of secondary boilers and a biochemical dephenolization unit, the rebuilding of the grog-producing shop in the refractory unit, and the providing of dust catchers, etc. The effluent of the coke byproduct plants in Nizhniy Tagil contains an appreciable volume of phenols, which, discharged into the Tagil river, pollute the entire Ob'-Irtysh basin. In solving the problem of purifying the effluent of phenols, scientists and planners decided to use it for quenching the coke. Thus, approximately 60% of the waste waters are vaporized into the atmosphere amounting to 250 m.^{3}/hr. and carrying up to 2 tons of phenol per day into the air. Its concentration in the central part of the city exceeds the allowable limit by almost 30 times. Installation of a biochemical dephenolization unit permits the air to be freed of phenols. Completing and putting in operation of an installation for smokeless charging of coke furnaces in coke byproduct plants is expected to have a great effect on the purification of air.

It is further foreseen that by bringing in natural gas, gas generating stations will be discontinued at the 'Uralvagonzavod', 'Uralmashzavod', 'Novotrubnyyzavod', and the Polevskoy cryolite plant, all of which contribute heavily to air contamination with phenols.

At the present time, in enterprises of ferrous metallurgy, 7 gas generating stations comprising 76 gas generators were closed down and the heating of open hearth furnaces was changed to oil.

The construction of the gas pipeline Bukhara-Ural and the arrival of gas from the North, from the Igrim and Berezovo fields in the Tyumen' region, will make possible the change of most boiler installations from solid fuel to gas. This will greatly reduce the discharge of ash and will be an important step in the purification of air.

Of great importance in combating air pollution from discharges of ventilating installations are the protective belts of green plants in the region of the Nizhniy Tagil plant, Polevskoy cryolite plant, the Pervoural'sk dichromate plant, and others. Thus, at the Nizhniy Tagil metallugical combine are planned 115 hectares of verdant plantings which are to surround the compound. To provide the required plants, a 27.5 hectares nursery is being established. In many factories and mills there were established the so-called "green watches" and much work has been done in an attempt to make the industrial areas verdant.

The administrative units of sanitation departments and those of basin inspection as well as the departments of water supply, and the agencies dealing with protection of water and air resources have carried out significant work of air purification. In this work representatives of science, engineering, and technology also have participated.

City councils of workers, area branches of the Society for Protection of Nature and its regional organizations as well as the general public have displayed great initiative in problems of green plantings in our cities and industrial enterprises.

INDUSTRIAL WASTES OF THE CITIES OF BAKU AND SUMGAIT AND THEIR EFFECT ON GREEN PLANTINGS.

R. O. Amirov, A. R. Ismaylov.
N. Narimov Azerbaydzhan Medical Institute

From Akad. Nauk SSSR Ural. Filial. Komis. po Okhrane Prirody. Rastitel'nost' i promyshlennye zagryazneniya. Okhrana prirody na Urale. V (Sverdlovsk, 1966), p. 37-38.

The two industrial centers of the Apsheron Peninsula -- Baku and Sumgait -- have a large variety of industires, specifically oil production and chemical industry.

The wastes discharged by these industries are large in quantity and severely contaminate the air, the watershed, and the soils with various deleterious chemical substances, such as carbon monoxide, sulfur dioxide, fluorine compounds, hydrocarbon vapors, chlorine, hydrogen sulfide, and the like. Systematic investigations of the degree and nature of air pollution in these industrial areas, which have been conducted since 1948, have established that in most cases the above waste products adversely affect green plantings whose function, at times, is to serve as a means of protection against smoke and gas. To this should be added that the natural environmental conditions of the Apsheron Peninsula (intense solar radiation; very low precipitation; lack of fresh water; greatly destructive northern winds; nature of the soil; dunes; and so on) are very unfavorable to the development of green plantings.

Our investigations showed that injury to green plantings depends essentially on the nature of the waste products. Thus, where the air is predominantly polluted by irritant gases (sulfur dioxide, chlorine, fluorine compounds, and the like) dark brown burns appear on the leaves. In addition, partly withered and some yellowed leaves were found. The growth of green plantings was arrested and the leaves were curling and dropping off. Externally, the trees and shrubs appeared as if fire-scorched. We have established that the toxic action of these pollutants strikes not only the plant parts above the ground but the root system as well. As the distance from the industrial compound increased, the frequency and the intensity of these injuries decreased.

Only some of the plants growing here are better adjusted to local conditions and manifest a greater resistance. Of the local ornamental species of greatest interest are: smooth-leaved elm, maple, pistachio tree, oleaster, almond, cotoneaster, willowleaf pear, honeysuckle, scarlet firethorn, oriental bladdersenna, arborescent jasmin, Turkey oak, and swamp oak.

The establishment and development of green plantings are important not only as a means of combating air pollution but also for the sanitary well-being of the industrial areas on the Apsheron Peninsula. This is particularly important because of the opening of the second branch of the Samur-Divichi Canal and the utilization and widening of the large Dzheyran-Batan watershed, which will greatly increase the industrialization of this region. In the establishment of green plantings in industrial zones it is necessary to take into account the following:

1. Plans of landscaping of industrial enterprises should include green plantings directly on the territory of the enterprises as well as in areas surrounding them in a radius of 150-500 m.

2. In view of the strong northern winds in the northern and northeastern parts of the peninsula, it is imperative to provide for the establishment of massive green shelter belts (one or two). These protective belts should be 500-1000 m. wide and planted with trees capable of developing large crowns.

Considering the toxicological nature of the pollutants and their tendency to accumulate in the soil, water, vegetation, and so on, the cultivation of fruit-bearing trees and bushes within these industrial areas should be avoided.

3. The selection of plants should be made by considering their gas resistance, their drought resistance, as well as the plants' ability to grow in solonchak-solonets, clayey, and clayey loam soils characteristic for the Apsheron Peninsula.

It is advisable to plant the trees and bushes by the trench method, i.e., by removing the salt-saturated upper soil horizons and filling the trench with salt free soil and manure. Because of the high salt content of the soil, irrigation with waste water (even after their intensive chemical purification) should be avoided.

GROWTH AND DEVELOPMENT OF ORNAMENTAL HERBACEOUS PLANTS IN COKE-CHEMICAL WORKS.

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From Akad. Nauk SSSR. Ural. Filial. Komis. po Okhrane Prirody. Rastitel'nost' i promyshlennye zagryazneniya. Okhrana prirody na Urale. V (Sverdlovsk, 1966) p. 173-176.

The Dnepropetrovsk Botanical Garden has conducted studies on the effect of smoke vented by the coke-chemical works on various ornamental plants.

Parallel studies were made for six years on the territory of a coke by-product unit in the city of Dneprodzerzhinsk.

These investigations dealt with 46 species of annual and perennial herbaceous, ornamental plants. The plants were grown in four plots, which were similar in their growth potential conditions but differed in the concentration of noxious gases. The air over three of these plots (A, B, and C) contained SO_2 ranging in concentration from 0.75 to 4 mg./m.^{3} and the fourth, a control plot, was free of noxious gases.

In the course of these studies the growth of the main stem and of various organs was determined. Phenological observations and the dynamics of dry matter accumulation at various stages of plant development were also recorded.

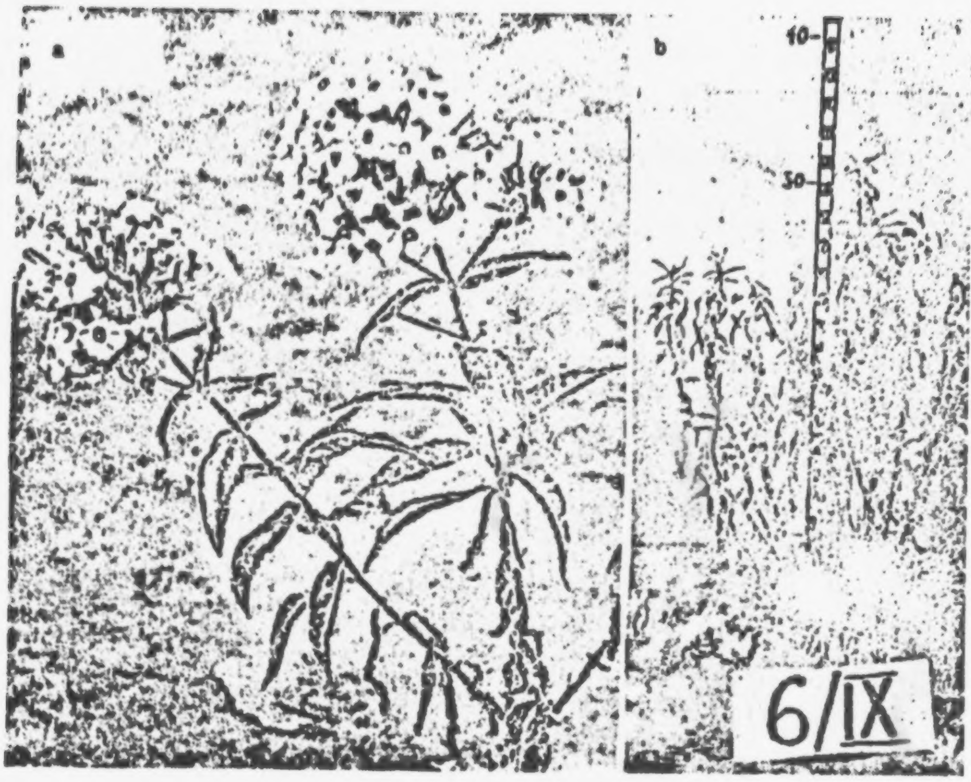
PLOT A. SO_2 CONTENT - 0.75 mg. per 1 m.^{3} OF AIR. The 46 investigated species of plants showed no appreciable change in the rate of growth. The test plants did not differ in height from the plants grown in the control plot. All bore fruit and produced good seed.

Smoke pollutants stimulated the growth of the Dahurian lily and of the whiterim camomile. The latter, for example, developed so well that it annually produces a heavy self-seeded crop, which invades the adjacent areas.

Only few species were visibly thwarted by small concentrations of smoke pollutants. Plants so affected were summer phlox (See Drawing) and hybrid peonies. Phlox was severely damaged, its pheno-phases were shifted, its inflorescence was poorly developed, producing frequently deformed flowers, and its seed was of low quality (Table 1).

PLOT B. SO_2 CONTENT - 2 mg. per 1 m.^{3} OF AIR. Of the 46 tested plants, 25 reacted slightly to the increased concentration of smoke pollutants. These were whiterim camomile, Dahurian lily, bigflower coreopsis, purselane, and other plants; they retained the rate of growth specific to them as well as the onset and the development of phenophases, and produced high quality seed.

However, 15 species of plants showed a higher sensitivity to an increased



Summer flux on plots with various sulfur dioxide concentrations: a - 0.75 and b - 2.00 mg./m^2

concentration of smoke pollutants. These included Chinese pink, great bellflower, Aztec marigold, and others. Thwarted growth processes are noted a few days after emergence, at which time the leaves begin to wither.

Some of the species had two periods in which the growth processes were most active. The first burst of growth occurred in May-June and the second in August-September. The latter continued to the end of the growing period. Such uneven rate of growth was caused not only by smoke pollutants, but also by weather conditions, i.e., by high temperature.

Thwarted growth processes caused changes in plant development and shifted the onset of phenophases. The vegetative growth was extended in the marigolds by 15 days, in Chinese pink by 10 days; the blooming of Drummond phlox lasted 79 days, and of marigold, 41 days.

There was a considerable difference between experimental and control plants in the number of flower buds and developed flowers. In the control plants 80-90% of the buds developed into flowers; in the experimental plants 30-40% of the buds withered prior to flowering, thereby shortening the period of mass flowering.

The flowers of the experimental plants were often few, small, and at times deformed. If the period from vegetative phase to blooming in the experimental plants was extended, then the period between flowering and seed ripening was shortened by 5-20 days at the expense of the flowering time. An increase in the concentration of smoke pollutants lowered the absolute weight of seed but did not affect their germination and the rate of development of the sprouts.

Five of the 46 plants in this plot either were dwarfed or lost their ornamental appearance. These five plants included the annual stock, dahlias, peonies, lodgepole lupine, and summer phlox. The experimental stock plant developed a luxuriant growth without signs of damage by the smoke pollutants; however, it did not reproduce itself and remained in a vegetative state to the end of the season. In some years, not over 10% of the plants flowered. Even so, the inflorescence was small and the flowers deformed and of poor color quality. Although the vegetative growth of the stock was normal, it lost its ornamental value.

Other plants in this group, dahlias and lupines, were severely damaged in some period of their growth by the industrial pollutants, and produced few and frequently deformed flowers.

The increased concentration of smoke pollutants greatly affects the important life processes of many plant species. Nevertheless, over 50% of the tested species react only slightly to increased concentrations of SO_2.

Table 1

Growth and development of Phlox paniculata on various plots.

Index	Control	A	B	C
Average height of plant, cm.				
June	15.6	13.1	11.1	4.2
July	40.2	35.6	25.1	9.2
August	43.2	36.7	25.1	Withered
Average number of shoots on one plant				
June	10.0	9.6	8.9	1.8
July	29.1	30.3	43.6	4.7
August	38.6	31.9	43.6	-
Leaf (length / width), cm.	6.0 / 3.1	5.1 / 2.0	3.0 / 1.5	1.5 / 1.0
Withered leaves, %				
June	0	0	10	30
July	5	25	40	80
August	10	30	60	100
Average number of inflorescences on one plant	35	27	16	-
Average size of inflorescence, cm.	7.6	5.3	4.1	-
Duration of blooming, days	116	76	43	-
Duration of vegetative period, days	164	134	92	66

PLOT C. SO_2 CONTENT - 4 mg. per 1 m.^{3} OF AIR. Of the 46 species tested 25 perished during the development of the cotyledons or of the first true leaves. The plants germinated well but after several days burns appeared on the cotyledons. The burns spread rapidly over the cotyledons, then to the leaves, after which the plant soon withered. Such was the case with rocket candytuft, Skinner columbine, garden balsam, and other plants.

The second group of 19 species were also strongly thwarted but the growth processes were not interrupted. Indeed, after some time the plants visibly revived and developed new shoots and leaves.

Compared with the control, the development phases of the experimental plants shifted. In most species the phase of vegetative growth was extended, and the duration of blooming, as well as of the entire growth period was shortened. Thus, the vegetative period of marigolds was extended by 50 days, of snapdragons, by 35 days, and the German iris bloomed only in the 3rd year after transplantation instead of in the 1st year as it usually does. The blooming period of experimental plants when compared with controls was shortened for the common zinnias 4 times, for marigolds 3.2 times, for iris 2 times, and so on.

The plants produced numerous small inflorescences and flowers. Only the first bud developed and the seed were not filled out. Although in some of the species the seed germinated well, the plants that they produced were weak.

Accumulation of dry matter is a reliable indicator of the state of plants. The control plants and those grown on plot A accumulated more dry matter in a given period of time than the same plants grown in plot B and, particularly, in plot C (Table 2).

Table 2

Accumulation of dry matter in Zinnia elegans zacq in the several plots. Average per one plant, mg. Denominator-percent of control.

Phenophase	Plant parts	Control	A	B	C
Vegetative	Above ground	267.1 100	246.1 92.1	167.2 62.5	22.2 8.9
	Roots	39.8 100	37.2 92.2	19.4 47.0	3.2 7.0
Budding	Above ground	1306.2 100	1290.3 98.7	930.6 71.2	412.3 31.5
	Roots	601.2 100	571.0 94.8	403.2 67.0	79.9 13.3
Blooming	Above ground	24362.0 100	23007.3 93.4	15290.0 62.7	2143.0 8.7
	Roots	3573.0 100	3020.2 84.5	1420.7 39.8	271.3 8.1

Based on the results obtained in this study, the following ornamental plants are recommended for planting in areas in which the concentration of SO_2 is 2 mg./cm.^{3} : hybrid aster, India canna, German camomile, showy camomile, bigflower coreopsis, Portola hybrid, hybrid gladiolus, garden iris, Dahurian lily, beardlip penstemon, fringed rudbeckia, Canadian goldenrod, hollyhock, Skinner columbine, Mexican floss flower, sweet alyssum, snapdragon, common feather cockscomb, plains coreopsis, summer cypress, Grecian stock, common purslane, purple scabious, and prostrate marigold. Under these conditions, 16 other species can also be planted.

Areas having an SO_2 concentration of 4 mg./m.^{3} should be planted with Mexican floss flower and plains coreopsis. Some other species that may be tested in such areas include: fruticose aster, hybrid aster, India canna camomiles, gaillardia, gladioli, Dahurian lily, coneflower, Canadian goldenrod, common purslane, scabious, prostrate marigold, sweet alyssum, and summer cypress.

THE EFFECT OF INDUSTRIAL GAS ON THE GROWTH OF TREES AND SHRUBS

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From Akad. Nauk SSSR Vsesoyuznoe botan. obschestuo. Botan. Zhurnal, Tom XLVII, 3, Mart, (Moskva, 1962) p. 412-416.

Industrial gases cause a disturbance of the physiological and biochemical processes of plants: repression of photosynthesis and transpiration, increase of the respiratory coefficient, a metabolic breakdown of the whole tissue, destruction of chlorophyl and vitamin C, and decrease of protein content. The industrial gases also cause a series of other pathological phenomena.

All of these disturbances must undoubtedly be reflected in the growth, development, and viability of plants.

In order to study the growth and viability of certain arboreal and frutescent species under conditions of smoke pollution, we laid out in the summer of 1959 three experimental plots in the Shchelkovo Forest of the Moscow district. These plots were located at various distances from the city of Shchelkovo. The experimental plots were established in the Shchelkovo Forest mainly because it is possible there to observe on a mass scale the loses sustained by coniferous species as a result of the presence of a high concentration of sulfur dioxide, nitrogen oxides, hydrogen sulfide, and hydrogen chloride.

The Erisman Scientific Research Institute of Sanitation and Hygiene demonstrated that the air in the vicinity of Shchelkovo contains the following quantities of harmful ingredients (Table 1).

Table 1

Gaseous components of the atmosphere near the city of Shchelkovo

Distance in meters and direction from the source of the pollution	Concentration of gases (in mg.) per m^3 of air			
	sulfur dioxide	nitrogen oxides	hydrogen chloride	hydrogen sulfide
$\frac{S*}{750}$	1.00	0.07	0.10	0.10
$\frac{S}{1000}$	0.70	0.09	0.60	0.25

* S = south

Katz wrote in 1941 that the exposure of plants to concentrations of sulfur dioxide greater than 0.4 mg. per cubic meter of air proved harmful to leaves in the period of growth, when physiological activity is observed to be highest and gas absorption reaches the maximum.

In our particular case, even at a distance of one kilometer from the Shchelkovo chemical plant, one cubic meter of atmospheric air contains 0.7 mg. of sulfur dioxide, which is almost twice the tolerable concentration (the surpassing of which results in injury to and destruction of plants). However, the degree of injury inflicted upon plants by industrial gases depends not only upon the concentration of these gases, but upon the duration of their activity on the plants.

It is necessary to note that of all the gases emitted by the Shchelkovo chemical plant the most harmful is sulfur dioxide by virtue of its great stability, high toxicity, and wide diffusion. Nitrogen oxides and hydrogen sulfide are easily neutralized.

The three control plots established in the Malakhov Forest were all subject to identical local growing conditions. There were no industrial enterprises near the control plots.

The test and control plots were established within plantings of pines and spruces which were either of intermediate age or approaching maturity, with a heavy undergrowth and regrowth of various arboreal and frutescent species. The taxonomic characteristics of the experimental and control plots are given in Table 2.

The experimental and control plots were divided into plantings undisturbed by cuttings; void of traces of windfalls, windbreaks, and mechanical injuries; and uncontaminated by butt-rot fungus, Fomitopsis annosa or Fomes annosus, and armillaria, Armillaria melea. The plots were located in places where there was no cattle grazing or hay mowing being conducted, i.e., in areas with an undisturbed phytocenosic environment.

The testing of the butt-rot fungus and armillaria contamination was conducted on standard trees cut from the number of shrinking pines and spruce. In each experimental plot four test trees were cut and analyzed. In the roots of the test trees there was no appearance of mycelia; there was a lack of both peripheral and central rot in the stump cuts.

Thus, fungus diseases, mechanical injuries, and cuttings through the plantings due to construction are not the causes of shrinking in the coniferous species nor of the reduction in growth of the deciduous species and brushwood. The shrinkage and growth reduction also does not result from cattle pasturage or hay cutting and soil compaction.

Consequently, the assumption remains that the cause of damage to the trees and brushwood is the industrial gases emitted by the Shchelkovo chemical plant.

The evidence of damage to trees and brushwood by industrial gas can be seen in the diseased needles and leaves and in the general deterioration of trees.

In all of the experimental plots near Shchelkovo, the pines and spruces, of from 50-60 years of age, suffer heavily: the crown dries and becomes defoliated.

Table 2

Taxonomic characteristics of the experimental and control plants

Plot no.	Forest	Section	Distance (in km.) and direction from pollution source	Composition of the planting	Average age (years)	Average diameter (in cm.)	Average height (in meters)	Bonitet (soil site index)	Fullness	Forest Type	Seedling Growth	Undergrowth	Ground Cover	Soil Type
Experimental no. 1	Shchelkovo	53	S / 2.5	10 pines	50	25.2	16.7	II	0.4	Piney, bilberry, grassy	Pine, spruce	Juniper, willow, spindle tree	Whortleberry, cowberry, cereals, green moss	Sandy loam, weak sod, strongly podzolic
Control no. 1	Malakhov	5	-	10 pines	50	27.2	15.5	II	0.4	Same as above	Pine, spruce, birch	Juniper, mountain ash, buckthorn	Cowberry, whortleberry, cereals, green moss	Same as above
Experimental no. 2	Shchelkovo	54	S / 3.0	Stage I: 9 pines, 1 spruce; Stage II: 10 spruces + oak, birch	Stage I: 70 Stage II: 40	Stage I: 27.9; Stage II: 20.6	Stage I: 21.4; Stage II: 17.7	II	0.7	Piney, bilberry, passing into whortleberry	Pine, spruce, oak, birch	Willow, mountain ash, buckthorn, raspberry, spindle tree	Cowberry, whortleberry, cereals, moss, asarum, lily-of-the-valley, fern	Sandy loam sod, medium podzolic
Control no. 2	Malakhov	27	-	Stage I: 10 pines + spruce; Stage II: 10 spruces + oak	Stage I: 80 Stage II: 40	Stage I: 34.4 Stage II: 17.3	Stage I: 23.5 Stage II: 16.7	II	0.7	Same as above	Pine, spruce, oak, birch	Filbert, buckthorn, raspberry, spindle tree	Whortleberry, cowberry, cereals, green moss, St. John's wort, asarum	Same as above
Experimental no. 3	Shchelkovo	56	S / 6.0	6 spruces 4 pines, + birch, aspen	60	31.6	20.6	I	0.5	Spruce, whortleberry, grassy	Pine, spruce, oak, birch, aspen	Mountain ash, buckthorn, raspberry	Whortleberry, cowberry, cereals, fern, majanthemum	Sandy loam, weak sod, medium podzolic
Control no. 3	Malakhov	36	-	6 spruces, 4 pines, + birch	80	29.4	23.6	I	0.7	Same as above	Spruce, oak, birch, aspen	Juniper, mountain ash, buckthorn, elder	Whortleberry, cereals, lily-of-the valley, majanthemum	Same as above

The pine needles change from dark green to a lifeless gray, become sickly, decrease in size, and adhere to branches of pines for 2 instead of 4 years and to those of spruce for 3 to 4 years, instead of 7 years under normal conditions. As a result of the decline in the size of needles and the reduction of their life span, the total assimilating surface of the tree is reduced, which, in turn, causes a reduction in the concentration of organic matter.

The life span of regrown pine and spruce needles is also cut in half, as is the case with the adult specimens. The needles of the young pines and spruces are greener than those of the adult trees. This evidently is explained by the greater stability of chlorophyl in the needles of the young trees.

The loss of the bright-green needles, the reduction of their life span, the appearance of a dark brown stain on the leaves, and the browning of the leaf tips are, as writes N. P. Krasinskiy (1937), symptoms of disease caused by gas emissions from industrial plants. Therefore, tree damage in our experimental plots may be explained only by the action of these gases.

Industrial gases act directly only upon leaves and needles. In the branches and root system they do not exhibit a direct influence. It should be noticed, however, that in trees and shrubs injured by the effects of industrial gases, the growth of both the major and secondary branches is decreased, and the total weight of the physiologically active roots is lower by far than in trees with a normal environment. The difference in root weight between weakened and healthy trees is most noticeable in spruce and pine.

The general weight reduction of roots and the weakening of growth are explained by the decrease of total assimilating surface of trees and shrubs as a result of the reduction of needle and leaf size; they are also explained by the reduction of the life span of the needles.

In the control plots, on the other hand, there was no visible injury to the trees and brush. Coniferous needle lifetime was normal, their color was dark green, and the tips did not turn brown. The pine and spruce crowns did not defoliate and there was no drying of the tops.

The purpose of our studies was also to investigate the effect of industrial gases on the growth of several forest-forming trees and shrubs in the Podmoskovian district. Towards this goal, the length increment of the main shoot of seedlings of pines and spruces was measured during the years 1957, 1958, and 1959. The length increment of deciduous species and brushwoods was measured for 1959 only. The linear measurement of length growth was made with an accuracy of up to 0.1 cm.

In all of the plots the increment of 100 specimens of each species was measured. In the case in which some species in the plot were represented by less than 100 specimens, only those available were measured. However, never was the quantity of data specimens less than ten.

The layout of the experimental and control plots, their evaluation and description were conducted in July through August of 1959, but increment measurements were made at the end of the growth period in September of that year, before leaf fall.

The results of the measurements of the length of increment are given in Tables 3 and 4.

Table 3

The effect of industrial gases on the growth of coniferous species

Distance (in km.) and direction from pollution source	Species	Growth in length (in cm.) under conditions of smoke pollution and in its absence					
		1957		1958		1959	
		Experimental plot	Control	Experimental plot	Control	Experimental plot	Control
$\frac{S}{2.5}$	Pine	14.2	21.4	15.6	31.1	13.2	30.0
	Spruce	15.5	17.0	17.5	20.0	12.6	21.0
$\frac{S}{3.0}$	Pine	11.5	19.0	13.0	21.0	12.1	18.2
	Spruce	12.5	13.4	9.0	10.5	9.4	17.0
$\frac{S}{6.0}$	Spruce	5.9	9.7	10.1	8.2	11.0	12.2

Table 4

The effect of industrial gases on the growth of deciduous trees and shrubs

Species	Growth of primary branches in length (in cm.)					
	2.5 km. from pollution source	Control	3 km. from pollution source	Control	6.0 km. from pollution source	Control
Oak	-	-	20.3	45.0	7.0	12.5
Birch	58.8	45.6	64.8	68.4	48.7	58.0
Aspen	38.1	82.0	34.0	55.7	27.6	50.2
Mountain Ash	17.0	24.0	24.1	28.5	19.3	19.8
Buckthorn	17.8	31.8	-	-	10.1	18.2

Tables 3 and 4 make clear that industrial gases inhibit growth in all of the species we measured, but in varying degrees. In the coniferous the increment in pines is sharply decreased; in the deciduous species, the increment in aspens is weakened. The gases affect the increment of birches the least.

At a distance of 6 km. from Shchelkovo the difference in increment of control and experimental trees is less sharply expressed. This, of course, is logical: the greater the distance from the source of pollution, the lower the concentration of harmful gases in the atmosphere.

On the basis of these studies that have been conducted, it is possible to draw the following conclusions: 1) under the influence of industrial gases there is a decrease in the size of needles and leaves; 2) the life span of needles is half what it would normally be; 3) as a result of the decrease in needle and leaf size and the reduction in the life span of needles, the assimilating surface of the trees and shrubs is sharply decreased; 4) the weakening of growth under the influence of industrial gases is observed in both the coniferous and deciduous species; the cause of the weakening growth is the repression of photosynthesis due to the reduction of assimilating surface; 5) with an increase in distance from the pollution source, the difference in growth between the trees existing under pollution conditions and those existing in the absence of such conditions gradually disappears.

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EFFECT OF INDUSTRIAL POLLUTANTS ON THE VEGETATION OF BASHKIR A.S.S.R.

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Based on its abundant natural resources the Bashkir A.S.S.R. has developed a large petroleum industry as well as a petroleum refining and chemical industry. In the next decade, the Bashkir Republic will become one of the large industrial centers of the U.S.S.R. Petroleum chemistry, machine building, non-ferrous and ferrous metallurgy will be further developed. In this connection, the problems of protection of atmospheric air, which is still often polluted by industrial discharges, are of paramount importance. Considerable effort should also be directed toward the protection of vegetation, which facilitates purification of air.

The program formulated by the K.P.S.S. envisions measures for greater improvement of living conditions in cities and other inhabited areas. These contemplated measures include: verdant plantings, water supply, and a vigorous fight against air, soil and water pollution. At present, many industrial enterprises, and particularly oil refineries, chemical, metallurgical and machine-building plants include units continuously venting gases noxious to vegetation. The chemical composition of the smoke gases varies in substance and, in most cases, these gases consist of complex mixtures of varying concentration. Thus, the refinery exhausts usually carry saturated and unsaturated hydrocarbons, carbon monoxide, hydrogen sulfide, sulfur dioxide, and others. The composition of the waste gases from the chemical industry is even more complex.

Dust particles, soot and smoke-black, discharged by some industries, are also injurious to the growth and development of plants. The lower layers of air, i.e., the zone where arboreal and herbaceous plants develop, usually contain the largest number and highest concentration of these pollutants.

Most plants, and particularly conifers, are very sensitive to gas pollution of air, which causes arrested growth and changes the color of foliage and needles. Even at small concentrations of gases, the edges of leaves curl, and foliage yellows, while at higher concentrations burns appear, and the leaves turn brown and wilt. This in turn causes premature, partial, and even complete defoliation. Yu. Z. Kulagin observed in 1961 that larches located near the Ufa refinery changed their needles twice in one growing season and finally withered. It should also be noted that gases in high concentrations burn and destroy the foliage of all arboreal species, without exception, including those usually considered gas-resistant. At high gas concentrations herbaceous plants also yellow and wilt.

In the literature cases are quoted where vegetation was affected at a distance of 30 and even 100 km. (U.S.A.) from the source of industrial pollution.

In Bashkiria, the adverse effect of smoke pollution on arboreal vegetation can be observed only in the immediate vicinity of some enterprises in Ufa, as well as in Beloretsk and Sterlitamak. Within the city limits of Ufa, the heaviest smoke pollution is found in the Ordzhonikidze section. In some parks of this district can be observed the injurious effect of smoke on trees. Thus, in the Pobeda Park, on a three-hectare plot of 96-year-old oak more than 20% of the trees had withered tops.

The proximity of a refinery affects plant development in the Pushkin Park. Here, a seven-hectare stand of 50-year-old oak and linden had more than 20% of top-dry trunks. An additional factor, adversely affecting tree growth, is a stack belching chemical waste. In the fall of 1950, 6-year-old box elder was set out on the Ul'yanov street in the vicinity of factories. The leaves in the box elder crowns curl up every year because of smoke pollution. In many places, the leaves drop during the summer. Up to 50% of the set-out trees perished because of the smoke. The remainder are stunted and their tops dried up.

Of greatest interest are data concerning the growth of various arboreal species in the verdant plantings on the grounds of the Ufa refinery. Here, in 1950 were set out: balsam poplar, little leaf linden, red ash, and box elder. In addition, a large assortment of ornamental shrubs was planted: European mountain ash, Tartar maple, Tartar honeysuckle, willow leaf spirea, white mulberry, hedge cotoneaster, hollygrape mahonia, European red elder, and Siberian pea shrub or pea tree. These plantings were made in predominantly heavy loam.

Red ash showed a remarkably high gas resistance under these conditions, and though its leaves curl, it is able to give an annual height increment. Nor were any dead plants found. The leaves of the little leaf linden also yellowed and curled. The leaves of the European white birch yellowed prematurely. It was noticed that the birch grew better when a building stood between it and the source of pollution. A hybrid Berezinskiy poplar also showed some gas resistance; its leaves did not curl and only slightly yellowed, even though some dropped.

Balsam poplar is more damaged under the same conditions. Its leaves not only became yellow, but also turned brown and their premature dropping occurs more frequently. In the immediate vicinity of industrial establishments where there are benzine vaporizing puddles on the ground, specific odors, and low air humidity, only 50-60% of box elder, Chinese elm, and balsam poplar survived, notwithstanding periodic hoeing and good maintenance practices.

The shrubs that survived the test proved quite gas-resistant, although the leaves of the mountain ash curled and those of Siberian pea shrub yellowed. The leaves of most shrubs, however, dropped before their time, in addition to already losing up to 20% of their leaves in summer.

Although fruit and berry species are relatively gas-resistant, an orchard consisting of 80 apple trees and 200 black current shrubs, located in the center of the refinery grounds, perished.

Besides industrial pollution, plants are also affected by pollutants resulting from our way of life, as for example from air pollution by the use of faulty automobiles, incapable of completely burning their fuel.

In the green plantings of the city of Ufa there were many young and old spruce trees. These trees grew up in places protected by buildings, on fertile loamy soil, adequately provided with water. The 120-year-old spruce were of mighty growth and covered by thick, dark green needles. They were mostly the green cone variety of the Siberian spruce transplanted while young from the nearby forest. The spruce trees described here were healthy and bore a normal abundant fruit. On the spruce trees, growing across from the Lunacharskiy Park, could be seen passing flocks of crossbills.

However, from the time the automobile traffic in the city increased considerably and along with it, exhaust gases of ethylated fuel polluted the air. The spruce trees started drying up, first along the main traffic arteries, then in areas more distant, and finally, even in outlying city districts. First, the needles lost their deep green color and turned light green. In the next stage of the tree poisoning by polluted air, yellow hues were observed to spread gradually over the light-green background. Along with color change, the needle cover thinned and bare tops appeared. Finally, there began a simultaneous withering of a great many spruce trees, starting with the oldest specimens.

The young trees, 20-30 years old, held their own for some time. However, within 5 to 6 years after the withering of the old trees, they too succumbed. Death of the trees, which started in the most gas-polluted sections, gradually spread, with the increase of air pollution, to the city outskirts. Spruce on the upwind side of the city survived longer, primarily in sections where fresh air was coming in from the outside, e.g., along Tukaev Street. They lasted longest in the sections of Old Ufa where automobile traffic was still sparse, but as traffic penetrated into the section, the spruce trees perished there too. In the suburbs, where the air is pure, spruce of the same age or even older, thrive even now (in the village, Milovka, and along the Oktyabr'skaya Revolutsiya Creek).

Pine was used to a lesser extent than spruce in green plantings in the city of Ufa. Observations have shown that the pine was somewhat more resistant to air pollution than spruce. A cluster of pines survive to date in the Matrosov and Salavat Parks.

Observations of the growth and development of various species in Ufa showed that under conditions of prolonged gas pollution of low concentration, all deciduous trees are more resistant than conifers, which retain their needles for several years (pine, spruce, and fir). This is explained (1) by the cumulative action of substances that penetrate over a period of years from the polluted air into the needles, and (2) by a slower recovery of the needles. The deciduous species are partly protected by annual foliage changes from the cumulative effect, while the conifers replace only 15-30% of their needles, depending on the species and conditions. Within any one species, under identical conditions, younger trees as a rule, are more gas-resistant than older ones. At the same time, under the same gas concentration, young leaves, which are still in the growing stage, are more damaged than leaves already formed.

Berezinskiy hybrid poplar, balsam poplar, and black poplar are relatively gas-resistant. The hedgerow rose shrub is relatively gas-resistant too. Comparatively little damage from gas is sustained by elm, linden, and apple trees as well as by the shrubs: Tartar honeysuckle, mock orange, black currant, raspberry, snowberry, lilac, and Siberian pea shrub.

European white birch, green ash, and mountain ash are of medium resistance to gas pollution. Box elder, Turkestan elm (also suffering from frost), Siberian larch, pine, spruce and fir are severely damaged, their growth stunted, and their lifespan shortened. The above given gas-resistance rating is only preliminary because the chemical composition of gases, their concentration and their physiological effect are quite different. Further study is needed in these areas.

It is recommended that protective plantings be established around industrial enterprises, in open areas between them, and directly on their grounds. These plantings should consist of thick, multi-stage tree and shrub plantings of poplar, linden, apple, hedgerow rose, Siberian pea shrub, Tartar honeysuckle, raspberry, and black currant. Such plantings will materially change the gas composition of air for the better.

However, the basic task in air pollution control, namely, the installation of smoke purifiers, automation of production, and maintenance of high degree of hermetization throughout the industrial processes to prevent unnecessary losses resulting from gas leaks into the atmosphere must not be forgotten. These measures will contribute materially to the improvement of public health as well as to the protection of forests, and will ultimately bring economic benefits.

Faulty operation of purifiers in oil refineries and sloppy work at oil wells result in big waste of valuable raw material and pollution of soil and rivers. The improper installation of pipeline through the River Sim resulted in waste of oil into the river, water pollution damage, and even partial destruction of aquatic and littoral vegetation. Along the shores, stunted trees with the base of their trunks completely oil smeared can frequently be observed. In many oil-polluted creeks of Bashkiria, aquatic vegetation is severely stunted. Thus, in the Oktiabr'skaya Revolutsiya backwater of the Belaya River in Ufa, where steamboats, barges, and other river craft tie up, there was once thriving aquatic vegetation. In the littoral zone near the shore grew beautiful water lilies and the delicate pink flowers of water lady's-thumb. Because of severe pollution of the water by oil and other petroleum products, this aquatic vegetation is confined to the far reaches of the backwater, beyond the village of Milovka. Due to the action of oil, the leaves of the yellow and white water lily died. Curly pondweed is particularly severely affected. The delicate leaves of this plant submerged in the polluted water turn yellow, then become brown and perish. The aquatic plants, such as duckweed, disappear rapidly. Most sensitive to oil pollution is star duckweed which perishes sooner than the common duckweed. The abundant aquatic vegetation in the Belaya River inlet near Blagoveshchensk vanished completely.

These examples show that pollution of air and water by industrial waste strongly affect terrestial as well as aquatic vegetation. It is imperative to undertake resolute measures for combatting the pollution of air, water and soil, in order to completely eliminate in the near future the adverse effects of industrial pollutants.

MEASURES TO ELIMINATE ATMOSPHERIC POLLUTION FROM "VTORTSVETMET" MILLS.

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From Akad. Nauk SSSR. Ural. Filial. Komis. po Okhrane Prirody. Rastitel'nost' i promyshlennye zagryazneniya. Okhrana prirody na Urale. V (Sverdlovsk, 1966) p. 59.

The settlements in the area where the lead-babbitt shops of the "Vtortsvetmet" mills are located suffer from heavy air pollution by lead oxides discharged in the gases from the water-cooled furnaces and from the shop ventilation system.

According to the data of the Sverdlovsk Regional Sanitation and Epidemiological Station the average daily concentration of lead in some cases at a distance of 200 m. was 0.085 mg./m.^{3} and at 1000 m. 0.026 mg./m.^{3}, i. e., 122 and 38 times the permissible limit for air in settled areas.[1]

To reduce the discharge of lead and to purify the exhaust gases from the water-cooled furnaces, a complex was installed comprising: a scrubber-cooler, a compound cyclone, and a bag filter of the type RFG-VI operating at 99% efficiency.

Following purification, the gases are discharged through an 80 m. stack. Total cost of the gas purification installation was 250.000 rubles.

A check of the air pollution showed that the average daily concentration of lead in the atmosphere beyond the 500 m. sanitation protective zone of green plants was lowered to 0.00035 mg./m.^{3} and less, i. e., does not exceed the permissible limit.

Therefore, the indicated purifying structures gave good results. However, in a zone of 350 m. from the lead-babbitt shop the average daily concentration of lead was 0.0013 mg./m.^{3}, i.e., slightly higher than the permissible limit. This was caused by the lead discharge in the ventilation and aeration air from the shops. Therefore, to improve the sanitation of the air in the settlement the discharge from the ventilators of lead-babbitt shops should be first purified in bag filters and then passed through an 80 m. stack.

In addition, to protect the population from the injurious effect of industrial discharges, it is necessary to include in the sanitation plans as a protective zone a belt of green planting, and to remove the construction of new housing farther away from the sources of pollution.

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[1] N. P. Tomson. Predel'no-dopustimye kontsentratsii svintsa v vozdukhe zhilykh rayonov. Vyp.l. M., Medgiz, 1952.

EFFECT OF PLANTINGS ON THE SANITARY AND HYGIENIC CONDITIONS OF DENSELY POPULATED SETTLEMENTS

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From Akad.Nauk SSSR. Ural.Filial. Komis.po Okhrane Prirody. Rastitel'nost' i promyshlennye zagryazneniya. Okhrana prirody na Urale. V (Sverdlovsk, 1966) p. 87-89.

In inhabited localities the increased pollution of air by gases, vapors, and aerosols is a corollary to the rapid development of industry and automotive transport. Near industrial enterprises and streets with heavy traffic of transport, such pollution is particularly high and exceeds the allowable concentration many times.

One of the most effective methods for combating air pollution is planting of greenery. At the Rostov Research Institute of the Academy of Municipal Economy in the MKKh of the RSFSR studies were made of the effect of different types of plantings in relation to large apartment buildings variously situated. Air samples were taken by the aspiration method and analyzed for their content of carbon monoxide, sulfur dioxide, and dust. This study showed that the best living conditions are in areas of widely spaced buildings, well provided with greenery, and separated from the traffic of the street by an 8 m. wide green strip. In such sections, the concentration of dust in July-August did not exceed 0.4-0.5 mg./m.^{3}, and of carbon monoxide 0.6 mg./m.^{3}. Residential blocks in the old central part of the city are in worse condition. These sections are densely built up, small in area, and have very little greenery. In these sections the concentration of dust is 2-3 times, and the concentration of carbon monoxide, 4-5 times that of the maximum permissible concentration.

The worst conditions were encountered in areas of widely spaced apartment buildings like the one first mentioned but having no green plantings (new buildings). The dust and the gases from the traffic carrying streets penetrate deep into the block, accumulate there, and create dust and gas pollution of the air, frequently worse than on the streets.

Studies showed that in the streets the dust content of the air exceeds 2-10 times and the carbon monoxide content, 2-5 times the permissible concentration. In all the residential sections studied the concentration of sulfur dioxide in the air did not exceed 0.1 mg./m.^{3}, i.e., was below the permissible limit. The smallest concentration of microorganisms was found in the first-described residential type (480 in 1 m.^{3} of air). In the traffic bearing part of the street their concentration was 3-8 or more times heavier.

The sanitary and hygienic conditions in a residential area are influenced not only by air pollution but depend on a variety of circumstances, such as temperature of the air and humidity, wind conditions, and the degree of solar radiation.

Observations made in Rostov/on Don in 1963 have clearly demonstrated the important effect of inner block plantings on the microclimate of the adjacent areas and on the creation of more favorable conditions of temperature, humidity, and wind as well as of better insolation conditions.

The observations were made in the same residential sections of the city in which air pollution was studied. The relative humidity of the air in the widely spaced and lavishly planted sections was 15-24% higher than in a similarly built section that was bare of greenery. The relative humidity of the air in the densely built-up section that was well provided with greenery throughout its area was 6% higher than a similarly built-up section devoid of green plantings.

In all the variously built residential sections having green plantings, the temperatures at the hottest time of day were 3°C. lower than in sections devoid of greenery.

Massive inner block plantings have a beneficial effect on the microclimate of the adjacent open spaces. The temperature curves in a heavily planted area and at a distance of 75 m. from it are analogous. Wind attains its highest velocity in a widely spaced section devoid of greenery. In those sections where buildings were widely spaced and well provided with greenery, the wind velocity decreased from the edge of plantings to their center, from 4 to 1 m./sec. at a distance of 100 m. In sections of closely spaced buildings, the wind velocity near the buildings was lower than in the adjacent open areas. However, within the grounds the wind velocity increased 1-5 times because of eddying.

In the southern regions of the country the decisive factor influencing the microclimate of a residential area is the short-wave solar radiation. Excess of direct solar radiation affects negatively the well-being of the inhabitants, and therefore devising means for reducing the level of solar radiation is of particular importance.

Actinometric observations were made with the aim of (1) determining the effect of green plantings on isolation of a residential section; (2) determining the radiation reflected from vertical surfaces as affected by the color of the latter and by the distance from them; and (3) determining the radiation reflected from horizontal surfaces as they are affected by the nature of the ground cover of the neighborhood.

Trees selected for these experiments were the ones widely distributed throughout Rostov/on Don: Eastern poplar, black locust, green ash, apricot, honey locust, Norway maple, horse chestnut, American linden, and others. Depending on the density and shape of their crowns, the trees variously affected direct solar radiation. Thus, in the hottest time of day, under an American linden at a height of 0.5 m. from its active surface, direct radiation is 100 times less and under a horse chestnut, only 55 times less than in an open space. Equally affected is the total radiation. A study of solar radiation under the crown of the other species showed that the spherical shape of the crown of the Norway maple reduced direct radiation 44 times, Eastern poplar 33 times, the apricot and ash 26 times, and the black locust 22 times.

In the southern cities the dominant role in establishing the heat balance is the radiation reflected from horizontal and vertical surfaces (walls of buildings, sidewalk pavement, street pavement, and other paved surfaces). To determine reflected radiation variously painted and vine-covered buildings were chosen. Reflected radiation decreased 1.2 times with the distance from yellow or gray painted walls, as well as from vine-covered walls. At a distance of 1 m. from a brick wall, the decrease of radiation is insignificant. Vine-covered walls had a very low albedo.

For the study of radiation reflected from horizontal surfaces, asphalt, spear-grass, compacted soil, and lawns were chosen. Spear-grass had the highest albedo, asphalt somewhat lower, followed by compacted soil, and lawn. Lawns and ivy-covered walls heat up very little, have a low albedo, and therefore are effective in lowering the air temperature.

The properties of green plantings -- capable of establishing a unique balance of radiation, heat, and moisture in areas where they grow and in the open spaces adjacent to them as well as their ability to regulate the air movement near the surface -- make them very essential factors affecting the sanitary and hygienic conditions of residential areas. Judicious planting, which takes into account local climatic conditions as well as the biological characteristics of the plants, will promote optimum microclimatic, sanitary, and hygienic conditions for the inhabitants.

RECOMMENDED PROCEDURES FOR PLANTING SANITARY-PROTECTIVE GREEN BELTS IN AREAS OF INDUSTRIAL ENTERPRISES.

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It is of paramount importance in our society to make more healthful the conditions of work, rest and living, and to protect the air against pollution. These problems arose during the industrialization of our country and increased during the present rapid development of industry.

To date, a great deal has been done in this direction. Industrial wastes have been classified on the basis of their injuriousness; permissible concentration limits have been established for industrial discharges into the air; distances from industrial enterprises have been fixed for locating settlements; norms have been worked out for residential construction; dust, smoke and gas controls have been installed in many enterprises; work is being done on improving the effectiveness of sanitary spacing, and the like.

All these measures, however, lag behind the rapid industrial growth. The air in industrial areas is still heavily polluted with industrial discharges, and in many instances their concentration exceeds the allowable limits.

Particularly affected are cities in the Urals, Donbass, Kuzbass, and other industrial regions. The excess of concentration of industrial pollutants over the permissible limits is a widespread phenomenon. Plants manufacturing synthetic fibers discharge into the air 60,000 $m.^3$ of toxic gases for each ton of their production. And yet, to date no methods have been developed for determining the concentration of injurious exhausts around these plants. A comprehensive program of measures to safeguard the purity of air has been devised. Where these measures have been taken, the quality of air is continuously improving. Thus, in the last few years a considerable number of dust and smoke catchers were installed in Moscow, many enterprises, apartment house furnaces, and heat supply installations for public buildings and residential units have been converted to gas; and many enterprises and individual shops, which formerly polluted the air, have been moved outside the city. Compared with 1950 the dust content in the city air has been reduced 5-6 times, the sulfur dioxide concentration has been reduced 3 times in comparison with 1956, and the construction of traffic tunnels has lowered the concentration of carbon monoxide and hydrocarbons 4-6 times. Similar work is being done in other large cities also. Planting of sanitation and protective belts is an important method in the sum total of measures for the protection of air in industrial cities. In planning green plantings for the sanitary-protective zones, the following problems should be solved: location of plantings, their concentration, selection of gas-resistant trees and shrubs, and the agro-technical methods of planting and care. The solution of these questions is tied to the specific purpose for which the greenery is intended in a given area.

It is frequently thought that verdant plantings are a potent and continuous natural absorber of noxious industrial discharges. With this assumption, it is concluded that if the polluted air passes through plantings it will emerge purified. This assumption, however, is baseless.

Green plantings cannot be counted as natural, limitless absorbers of toxic gases. In addition, depending on the geographic location, trees and shrubs have no leaves for 5-7 months. Coniferous trees and shrubs, which retain their green foliage during the winter are, as a rule, non-resistant to industrial pollutants. When the air is polluted by various aerosols, dust, soot, smoke, etc., green plantings will retain the suspended particles on their leaves, branches, and trunks, and the rain will wash them down.

The decisive measures in combating air pollution by industrial discharges of noxious gases are the installations of smoke and gas catchers and recuperator units, and their effective maintenance.

Although green plantings cannot act as absorbers of industrial discharges of injurious gases, their function in sanitary-protective areas is indeed great. Besides their usual function, such as enrichment of air with oxygen, ornamental aspects, and the like, properly designed green plantings in sanitary-protective areas, can and should perform the following important functions:

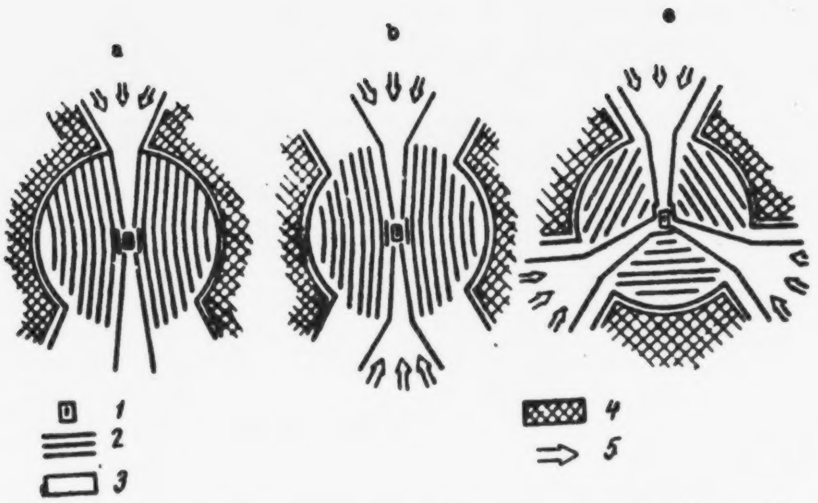
(a) Contribute to systematic ventilation of the area and insure the diversion of polluted air in a most convenient horizontal direction and away from residential and industrial areas;

(b) Contribute to the formation of vertical air currents to carry off polluted air from the area and to disperse it in higher atmospheric layers (accomplished in summertime by the lowering of air temperature over the plantings and by the rise in temperature over bare or over specially paved areas) and, in wintertime, by converse conditions.

(c) Purify the air of aerosols, dust, soot, and smoke.

To insure the ventilation of the industrial installation and of the sanitary-protective zone, the green plantings should be located so that a special passage is provided leading through the point at which the noxious gases are discharged or through the point at which their highest concentration in the area is known. The direction of this passage should coincide with the direction of the prevailing winds.

If the direction of the prevailing winds is variable, then it may be necessary to provide two or in some instances three such passages going through the same point in the area of the industrial enterprise. Their width should be 100-120 m. To increase the velocity of the air current and accelerate the ventilation, the passages should be somewhat constricted (10-15%) within the area of the industrial unit. There should be no high plantings, buildings, or other barriers which would impede ventilation (See figure). No residential units should be located at the exit of the green passages.



Rules for locating forest strips in sanitary protective zones in accordance with the direction of prevailing winds in the area of an industrial establishment.
a.- constant uni-directional winds; b.- winds from opposite directions; c.- changeable wind directions; 1.- location of industrial unit, source of air pollution; 2.- sanitary protective strips; 3.-open spaces; 4.- residential districts; 5.- wind direction.

Green plantings in the sanitary-protective zones should have the following characteristics:

(a) They should be continuously ventilated, i.e. that they should not collect noxious industrial discharges;

(b) They should be capable of maximum reduction in wind velocity in the direction of the residential areas;

(c) The trees and shrubs of these plantings should have the greatest possible branching and leaf coverage;

(d) The methods of green plantings of the sanitary-protective zones (i.e., the principles of location, layout, and field practices) should be as economical as possible.

Considering these points, the planting of the sanitary-protective zones in the shape of a dense forest-like unit, and particularly when horizontally closed, is inadmissible. Such dense forest-like plantings are not ventilated; they collect polluted air. Their planting and maintenance are expensive and require vehicles, labor, and planting material; in addition, dense plantings impede branching and leafing of trees and shrubs so that the foliage concentrates solely at the top.

All the basic requirements are satisfied by narrow-strip plantings with a distance of 40 cm. between the strips. Narrow forest strips of 7-8 rows are set out along the direction of the prevailing winds and are designed so that there would be constant ventilation between the strips. This, however, is advisable in cases where planning norms are followed, i.e., where the residential area is not located down-wind from the industrial area.

The most distant rows of the narrow forest strips should be planted with low or medium height shrubs; behind these should follow tall shrubs; and the two middle rows should consist of trees of the main species; and the rows between the tall shrubs and the main tree species should consist of sprouts of rapidly-growing tree species. Such a stepwise layout of forest belts provides the greatest density of planting, the best branching and leaf coverage of trees and shrubs, because actually each of the rows is fully exposed as if it were on a fringe.

To make mechanized maintenance cheaper, the distances between rows in the forest belts are 2.5-3.0 m. Because of this, the distances between the plants within the rows should be made smaller than those that have been recommended till now, i.e., the distances should be 0.5 m. for trees and 0.4 m. for shrubs. Such distances within the rows provide for a very great density of planting and a high degree of wind protection effect; and at the same time, sufficient area for plant feeding is allowed.

Based on research and experimental results of planning and of production units, the landscape sector of the K. D. Pamfilov Academy of Municipal Economy worked out "Tentative technical guidelines of planning green plantings in sanitary and protective zones of industrial enterprises" (Vremennye tekhnicheskie ukazaniya po proektirovaniyu zelenykh nasazhdeniy v sanitarno-zashchitnykh zonakh promyshlennykh predpriyatiy); these were approved for use by the Ministry of Municipal Economy of the RSFSR.

SMOKE RESISTANCE OF WOODY PLANTS AS AN ECOLOGICAL PROBLEM.

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From Akad. Nauk SSSR. Ural. Filial. Komis. po Okhrane Prirody. Rastitel' nost' i promyshlennye zagryazneniya. Okhrana prirody na Urale. V (Sverdlovsk, 1966), p. 25-27.

The problem of smoke resistance of woody plants has been studied by many investigators for over half a century, yet it remains unsolved. Particularly inadequate are the following: (1) the evaluation of the actual gas and smoke resistance of various species of trees and shrubs; (2) the understanding of some of the cuases of unsuccessful establishment of green plantings and reforestation efforts in industrial areas, and (3) the development of effective methods of achieving better results with plantings and reforestation efforts within industrial regions.

Quite naturally, the task of assembling a smoke-resistant assortment is based essentially on determination of the degree of vulnerability of leaves, and on grouping the species into three catagories: recommended, admissible, and non-recommended. However, in so doing, a rather important consideration is being ignored, namely: what are smoke conditions for which one or another species is being recommended, and what are the smoke conditions which make these species unsuitable. The question of ecological specificity of various conditions of smoke is generally not considered, and the role of external conditions in smoke resistance of plants is thought of as insignificant, provided that "the conditons are such that the plants can develop relatively normally" (Shabiolovskiy and Krasinskiy, 1950).

The ecological concept of smoke resistance in plants (Kulagin, 1962) was the basis of our investigations on the territory and surroundings of the metallurgical and petroleum refineries of the Chelyabinsk and Orenburg districts, and in the Bashkir A.S.S.R. The basic requirements were (1) a differentiated approach to the factor of smoke pollution in order to separate ecologically different conditions and establish on this basis smoke pollution zones; (2) determination of the smoke resistance factors of a given species as applicable to the specific smoke pollution conditions, the latter determination being made in the light of the dust and gas sensitivity of leaf-covered shoots of thses species, as well as in the light of their morphogenesis and resistance to other unfavorable aspects of their environment.

Conditions of smoke pollution should be distinguished by considering the physico-chemical properties of the toxic components in the smoke, the intensity of gas and dust effects, the frequency of their occurrence during the growing period, and their annual recurrence. The basic conditions of smoke pollution include constant (annual), periodic (once or twice during the growing period), and sporadic (non-annual) occurrence. In the case of periodic and sporadic smoke pollution there are situations of early, mid-and late summer smoke effects, which, although somewhat similar, may cause the damaged shoots either to perish or to survive, depending on their stages of growth. The latter depends on the degree of development of the shoots, their resistance to summer desiccation, and their ability to regenerate their leaves.

Many investigators consider the European white birch as non-resistant to gases and include it in the non-recommended group.

However, in the neighborhood of the Karabash copper smelter (southern Urals) the birch is a successful forest builder, notwithstanding the annual average and strong gas burns of the leaves. It should also be noted that the soil and climatic conditions of the Urals are not as favorable for the birch as are the European parts of the U.S.S.R., although they do not interfere with the normal growth and development of the birch. The reason for the resistance of the European white birch is the timing of the smoke. Because of the peculiarities of the climate, the gas attack upon the trees occurs in the second half of the growing period, at a time when all the important processes of growth, sprouting of shoots, blooming, and seed development are essentially complete. It can thus be said that ecologically such smoke conditions are equivalent to early frost, which shortens the growing period of the birch and causes a premature but not dangerous onset of autumn.

The effect of smoke depends on conditions of the surroundings; hence, its phytotoxicity varies greatly. As examples let us examine the damage (in %) to the leaves of the linden tree and the European birdcherry caused by 20 g./m.^{3}. hr. of SO_2, applied at different times of the day:

	Morning	Noon	Evening	Night
Linden tree	2	20	1	0
Birdcherry	1	5	0	0

This demonstrates a marked increase in the damage to the leaves at noontime and an absence of gas burns at night. There is also evidence of a sharp drop in the toxicity of SO_2 in the shade:

	Gas concentration in g./m.^{3}. hr.	Forest	Fringe
Leaves in sunlight	10	0	5
	20	0	20
Leaves in the shade	10	0	15
	20	0	40

Under the canopy of a closed stand of an oak-linden forest, the gas burns on the leaves of an English oak disappear on trees shielded inside the forest as compared with leaf burns found on trees at the fringes, and this is true not only for the xeromorphic and less gas susceptible leaves in full sunlight but also for those in the shade.

The ecological concept of smoke resistance of trees requires a recognition of the so-called critical periods when the sensitivity to toxic compounds is greatest and, consequently, the damage is higher and results in subsequent destruction of the entire plant. The critical periods are connected with: (a) weak morphological defense of tender shoots; (b) inability to regenerate leaves; (c) the injury is followed by unfavorable weather conditions, such as drought or frost. Thus, it was found that the critical period for conifers (pine and spruce) dusted with powdered magnesium oxide is early summer, a time when the coniferous needles are being formed. A strong attack of sulfur dioxide in early or midsummer is lethal for pine, spruce, lilac, honeysuckle, barberry, snow-berry and other species having a weak capacity of leaf regeneration. A late summer exposure to sulfur dioxide is not injurious to them. The red ash succumbs to midsummer injuries, when its shoots regenerate the leaves, but the loss of leaves in late summer is ecologically equivalent to an early fall, and therefore safe. Oil refinery gases are stunting to young shoots and leaves of elms, European white birch, pubescent birch, red ash, and ash-leaved maple. The withering of the first four species is caused by summer drought when the weakened leaves drop off. Ash-leaved maple perishes from winter frost because its shoots, only slightly lignified, extend their growth into autumn. Thus, fixing the critical period must account for the nature of the phytotoxicity of smoke and the morphogenesis of the shoots. The relationship of critical periods and smoke resistance of trees is useful not only in the selection of highly resistant varieties for landscaping and reforestation of the surroundings of the Ufa oil refinery, of the Karabash copper smelter, and the Satkin magnesite plant, but also in working out concrete plans for these enterprises in order to minimize the pernicious effect of smoke from these plants on vegetation. The recommendations should stress the necessity of continuous use of smoke purification units, their effective performance during the critical period, and postponement of their reconditioning to autumn and winter.

Thus, the phytotoxic compounds carried by smoke from industrial plants should be considered as an ecological factor, lethally acting first and foremost on the leaves. The degree of toxicity of industrial gases depends greatly on the conditions of the surrounding atmosphere. Destruction of leaves does not necessarily mean destruction of the entire plant. The destructiveness of the toxic gases is largely determined by the time of their incidence. The survival and regeneration of normal life activity of trees is determined by the extent of the maturity of their shoots and their resistance to the subsequent weather conditions. The selection of highly smoke-resistant trees and shrubs will succeed only when we learn to recognize the specific ecology of various environmental conditions and zones of smoke polluted areas in need of green plantings and reforestation.

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STUDY OF PHYSIOLOGICAL INDICES OF TREES AND SHRUBS IN RELATION TO GAS AND SMOKE RESISTANCE

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Karaganda Botanical Garden, Academy of Sciences, Kazakh SSR

From Akad. Nauk SSSR Ural. Filial. Komis. po Okhrane Prirody. Rastitel' nost' i promyshlennye zagryazneniya. Okhrana prirody na Urale. V (Sverdlovsk, 1966), p. 39-44.

In the Karaganda industrial region, in addition to the damage caused by droughts and drying winds, the damaging effect of smoke and gas on plants can also be observed. In view of this, and with the purpose of selecting the most resistant species for plantings, we have undertaken to study the peculiar physiological processes occurring in the plants under influence of smoke and gas.

The investigation was carried out during a period of four years in the Botanical Garden of Karaganda, and in the central Ore Dressing Plant, at the Temir-Tau Metallurgical Mill. To this end, the following trees, all of the same age, were planted in the above places: box elder, pinnately-branched elm, common lilac, oleaster, balsam poplar, Tartar honeysuckle, Siberian pea tree, Scotch pine, European white birch, brittle willow, Hungarian lilac, Tartar maple, and sweetbrier. These plants were studied in relation to growth and development characteristics, water conditions, intensity of photosynthesis, carbohydrate and nitrogen metabolism, differential oxidation of cell content, and the dynamics of chlorophyll accumulation.

The water conditions were determined by the following indices: water content--gravimetrically, bound water--refractometrically, transpiration intensity--by the L. A. Ivanov method, water retention ability of the leaves--by the A. A. Nichiporovich method, photosynthesis intensity--by the S.V. Tageeva method, dynamics of chlorophyll accumulation--by the Getri method, differential oxidation of cell content--by the N. P. Krasinskiy method, dynamics of carbohydrate accumulation--by the Kizil' method, and the determination of carbohydrates by the Bertrand method. In the study of the above enumerated aspects during the growing period, the nature of gaseous and dust discharges in the air was always noted. Gas and dust determinations were made by the Karaganda sanitary-epidemiological station.

In all plots, and particularly on the territory of the Metallurgical Plant, the air contained appreciable dust and smoke. The concentration of CO on certain days reached 64 and of SO_2 -- 5.3 mg./m.^{3} .

The territory of the Botanical Garden is in somewhat better condition. Because of the discontinuance of coal mining in the vicinity, the gas and dust concentrations in the air declined, and therefore the plants growing within the Botanical Garden were considered to serve as control plants.

In several of the species (Siberian pea tree, oleaster, elm, and box elder) the initial development phases in the smoke polluted areas occur earlier and pass faster than in the plants within the Botanical Garden. In addition, in 1963, on the territory of the Metallurgical Plant there was observed considerable gas injury to the leaves, which in many species caused leaf-drop in the middle of July, and in some species (such as brittle willow and Hungarian lilac) there was also observed second leaf development.

The growth of shoots is an important biological indicator. In this respect the studied plants can be divided into two groups of which the first--comprising oleaster, Tartar honeysuckle, European white birch, and Hungarian lilac--is characterized by an intense growth in smoke polluted areas, whereas the second group--comprising box elder, Scotch pine, and black locust--had an arrested growth of lateral shoots. In the Botanical Garden the growth was most intensive in plants of the second group. The pinnately-branched elm and the common lilac take up an intermediate position between two groups; the rate of growth of their shoots in the smoke polluted plots varied from year to year and with the age of the plant.

It is known that the water conditions in plants are intimately related to their various physiological processes. The water conditions strongly affect metabolism and the ratio between anabolism and catabolism. Hence, (1) the water supply during a period of intense physiological activity, (2) the water content of tissue, and (3) the ratio of the forms of water in the organs during the vegetative period--constitute important factors in the gas-smoke resistance of plants. Of great importance are the characteristics of transpiration, which to a large extent insures the feeding of the root system and of the aerial parts. Therefore, it is necessary to study the transpiration ability of plants in order to evaluate their viability under new ecological conditions.

Our results show that among the weakly transpiring plant species the following should be included: the box elder, the European white birch, the common lilac, and the Scotch pine. These species have a very low transpiration index in smoke polluted areas. The oleaster, the pinnately-branched elm, and the balsam poplar transpire very intensely when grown in smoke polluted areas.

In all the species transpiration appeared labile, and dependent on the weather conditions and the state of the organism. Two types of diurnal course of transpiration intensity of the plants studied can be noted:

1. The transpiration took place with a gradual increase during the course of the day and with a slight decline at certain periods; this type of transpiration is characteristic of conditions in which there is a sufficient water supply and was observed in the oleaster, Tartar honeysuckle, balsam poplar, box elder, and common lilac (Fig. 1).

2. The course of transpiration was characterized by fluctuations with a maximum taking place between 12 noon and 2 PM. These fluctuations were apparently connected with the extreme meteorological factors. The amplitude increased with the ability of the species to decrease the water loss. This type of transpiration was observed in the pinnately-branched elm, European white birch, Siberian pea tree, and Scotch pine (Fig. 2). The process of transpiration in the

studied plants was related to the growing conditions. In the species that had shown a high transpiration capacity the drop in transpiration was clearly expressed in plants grown on the smoke polluted plots. Plants with a low transpiration capacity growing in smoke polluted air have frequently shown a heightened transpiration intensity.

A study of the water content of leaves of various plants showed that their water content changed regularly during the growing period. At the beginning of July this index decreases and the water content rises only at the end of the growing period.

There were also variations in the bound water content. In the resistant species its quantity increased when grown on smoke polluted plots; it also increased from spring to autumn. The plant species with low smoke and gas resistance had a higher content of free water and a lower quantity of bound water (Table 1).

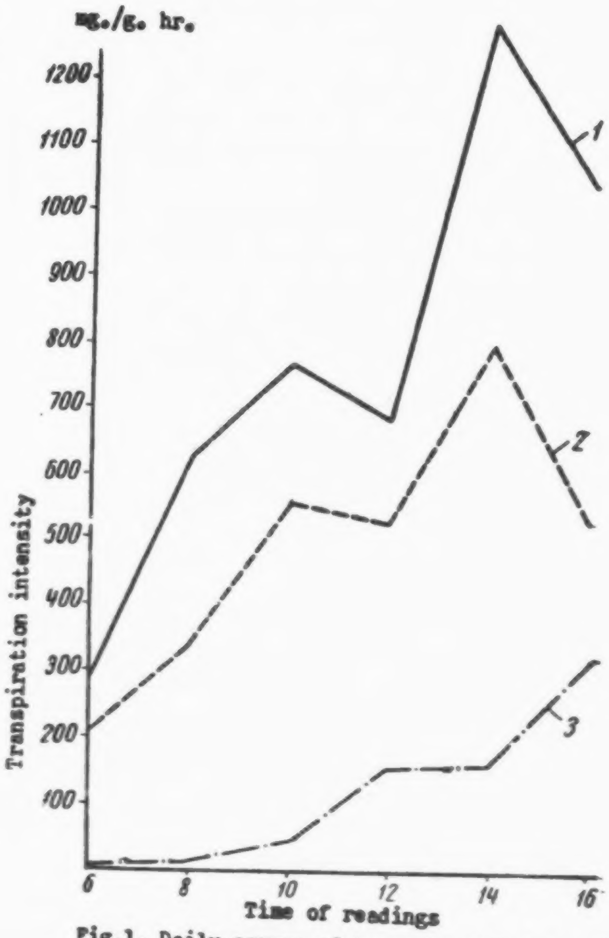

Fig.1. Daily course of transpiration intensity of russianolive on july 16, 1962

1.- Botanical garden; 2.- Ore dressing plant; 3.-Metallurgical plant

It is known that the water-holding capacity of leaves characterizes the ability of plants to withstand dehydration. Our observations have shown that the water retention capacity in most of the species changes during the growing period, increasing from spring to autumn. The smoke-resistant species had a greater water retention capacity, particularly toward the end of the growing period. This was true also for plants growing in smoke polluted plots, which undoubtedly indicates the adaptive capacity of these plants (Fig. 3). A lowering of the water retention capacity when grown on smoke polluted territory was observed in the European white birch, the common lilac, the Hungarian lilac, and the Tartar honeysuckle. The smoke-resistant box elder and balsam poplar behaved differently. In these species the water retention capacity changed with the weather. Thus, in the dry 1962 an increase in the water retention capacity was noticed in plants in smoke polluted areas, particularly toward the end of the growing period; and in 1963 smoke pollution caused a lowering in the water retention capacity throughout the entire growing period.

A study of the dynamics of chlorophyll accumulation in leaves showed in

Table 1

Percentage of Water content in the leaves of trees and shrubs

Species	Location	June 1, 1963		July 16, 1963	
		Total water	Bound water	Total water	Bound water
Balsam poplar	Botanical Garden	71.1	20.8	69.5	35.2
	Ore concentration mill	71.9	49.1	71.0	16.3
	Metallurgical plant	77.0	31.5	76.8	-
Common lilac	Botanical Garden	71.0	39.2	66.2	28.2
	Ore concentration mill	67.9	58.7	65.3	-
	Metallurgical plant	73.0	40.3	65.1	12.1
Box elder	Botanical Garden	76.3	29.7	71.9	10.8
	Ore concentration mill	75.0	34.3	72.2	17.8
Pinnately-branched elm	Botanical Garden	73.5	22.2	67.7	28.2
	Ore concentration mill	69.2	24.4	65.7	44.4

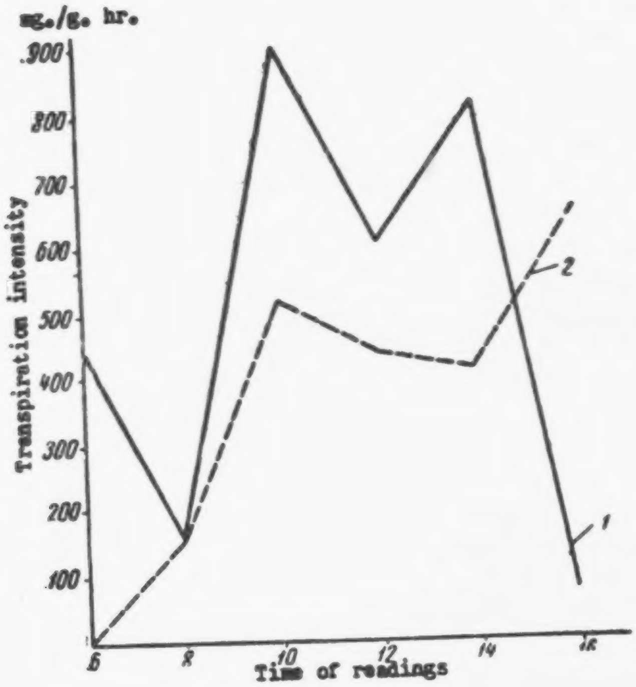

Fig.2. Daily course of transpiration intensity of pinnate elm on June 29, 1962. 1.-Botanical garden; 2. Ore concentration plant

most species a lowering of its content with the aging of the plant. In species resistant to smoke pollution there was an increase in the chlorophyll content in smoke polluted plots. The plants of this category included the oleaster, the pinnately-branched elm, and the balsam poplar.

One of the most important physiological processes in plants is photosynthesis. This process is intimately related to all of plant life functions and to the principal links in metabolism. In our experiments (Table 2) the most smoke resistant species (namely: the pinnately-branched elm, the oleaster, and the balsam poplar) accumulated in their leaves an appreciably greater amount of dry substance, which was particularly pronounced in the case of plants grown on the territory of the Ore Dressing Mill. In the rest of the species smoke pollution reduced the accumulation of dry substance. An analysis of the results of seasonal variations in photosynthesis showed that in most of the studied species there were two maxima, of which one coincided with the beginning of July and the other, with the end of July and the beginning of August.

Table 2

Photosynthesis intensity of woody plants, mg./dm.^{3} hr.

Plant	Location	Jun.25-Jy.17,1963				Jun.12-Jun.15,1963			
		Hour of Reading							
		9	11	13	15	9	11	13	15
Oleaster	Botanical Garden	280	330	170	370	280	460	330	520
	Ore concentration mill	470	340	350	600	600	320	410	570
	Metallurgical plant	240	280	280	460	590	590	340	790
Pinnately-branched elm	Botanical Garden	310	300	710	270	470	610	460	350
	Ore concentration mill	380	440	510	420	620	650	470	700

Thus, the photosynthesis process reflects on the one hand the biological peculiarities of the species, and on the other the ecological conditions in which they grew. It can, therefore, serve as an indicator of the adaptation of a plant to its habitat.

The importance of carbohydrates in plant life is particularly great. They are a source of nutrition and energy, and play an important role in plant metabolism. The role of carbohydrates as means of protection in adverse surroundings is equally well known.

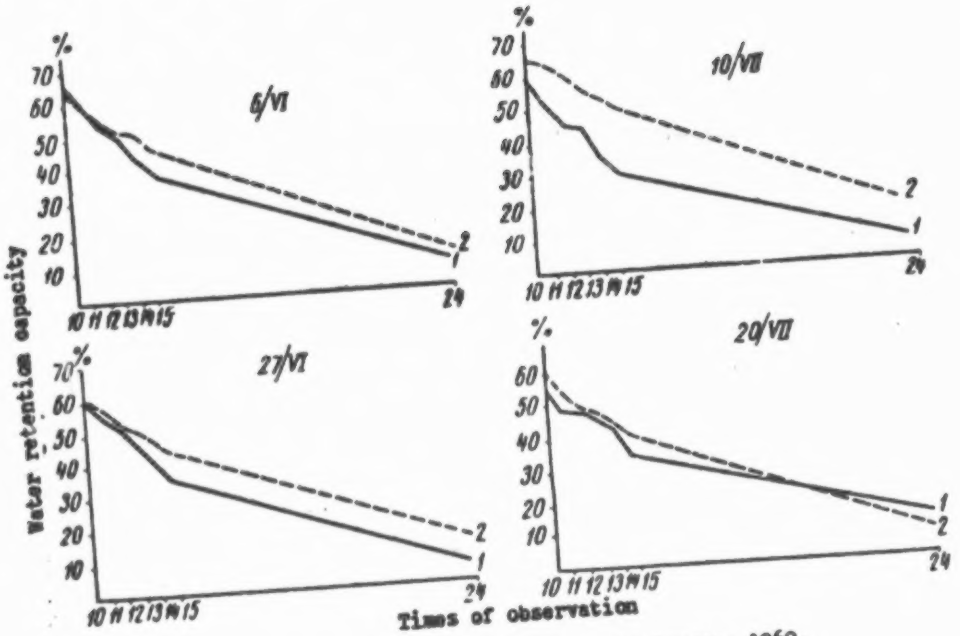

Fig. 3. Water retention capacity of pinnate elm leaves, 1962.
1.- Botanical garden; 2.- Ore concentration plant

Analyses of the data concerning changes in the sugar content during the growing period of the species studied lead to the conclusion that the sugar content is highest in the leaves during the period of most active growth, and decreases at the end of the growth period. It has been also found that with all species studied disaccharides predominated over monosaccharides of all the dates of sugar analyses. The monosaccharide content changed insignificantly during the growing period. Variations in the content of carbohydrates are attributable to the lowering of the disaccharides, which are the most labile forms of carbohydrates.

The high resistance to smoke pollution found in the pinnately-branched elm, the oleaster, and the balsam poplar is, to a large extent, due to the increase in the sugar content of leaves in those species when grown on plots subject to gas and smoke. This observed phenomenon confirmed the protective action of carbohydrates.

On the basis of the above presented studies, the species investigated can be arranged in decreasing order of their resistance to smoke and gas as follows: the pinnately-branched elm, the oleaster, the balsam poplar, the box elder, the Tartar honeysuckle, the common lilac, the Siberian pea tree, the European white birch, and the Scotch pine.

MOISTURE CONDITIONS AND GAS RESISTANCE OF WOODY PLANTS.

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The relationship between water conditions of woody plants and their gas resistance is of importance in the selection of highly gas-resistant species on the basis of the specific water conditions and degree of drought resistance. It is also of importance in raising the gas resistance of plants by changing the water conditions.

There is an opinion (Ilyushin, 1953) that drought-resistant trees are also gas-resistant. This thought, although of considerable interest, is not well-founded. To understand this question better, we have selected a number of species differing in their degree of drought resistance and the nature of water conditions in their leaves (Table 1).

Table 1

Water condition of some trees

Species	Water content, % of raw weight			Water retaining capacity, %	
	total	free	bound	after 8 hrs.	after 24 hrs.
Sukachev larch*	67.4	9.1	58.3	82.6	53.5
Siberian pea tree	62.2	24.2	38.0	17.9	3.6
European white birch	67.0	17.5	49.5	73.6	17.0
Pubescent birch	67.6	12.9	54.7	75.0	24.5

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* The analyzed needles grew from wintered buds.

The Sukachev larch and the Siberian pea tree are regarded as highly drought-resistant in comparison with the European white birch, and particularly with pubescent birch, which prefers soils permanently moistened and of higher water content. It should be noted that the leaves of the pea tree are characterized by unstable water conditions in comparison with the needles of the larch. This is shown by a higher free water content (extracted from the leaves with a 30% saccharose solution), low bound water content and low water retention capacity determined by the amount of water remaining in the leaves after air-drying as percentage of the original content. During strong summer droughts the leaves of the Siberian pea tree wither. The viability of the pea tree is guaranteed to a large degree by the high resistance to desiccation of the leafless shoots, a condition aided by early summer formation of shoots and buds. The gas resistance of the leaves of the selected species varies. Whereas sulfur dioxide damaged the needles of the larch 100%, the leaves of the pea tree sustained burns only on 80%, the European white birch on 50%, and the pubescent birch on 70% of the total leaf area. Thus, the larch and the pea tree, although most drought-resistant, are least gas-resistant. Apparently, this is caused by very weak external cover on their leaves (Knyazeva, 1950). By comparing two varieties of birch, it can be seen that a higher drought resistance is paralleled by a higher gas resistance. The higher gas resistance of the European white birch is directly connected with their considerable xeromorphism as compared with the pubescent birch. However, the extent of oxidizability of the cell content is of great importance in determining the gas resistance of leaves (Krasinskiy, 1950). Our data reveal the absence of decisive influence of cell content oxidizability on gas resistance:

	Total cell content oxidizability in ml. of 0.1 N-$KMnO_4$ per 1 g. of	
	fresh matter	dry matter
Sukachev larch	33.0	95.1
Siberian pea tree	32.2	91.2
European white birch	39.2	108.6
Pubescent birch	29.2	104.3

It is, therefore, necessary to accept the fact that the dominant factor in gas resistance of leaves is their structural characteristic.

If the nature of the water conditions in the leaves is not the main condition of their gas resistance, it is still necessary to probe the changes in the water conditions of the various species affected by toxic gases (Table 2).

Table 2

Water condition of leaves growing under various conditions.

Species	Where grown	Water content, % of raw weight			Water retaining capacity, %	
		total	free	bound	after 8 hrs.	after 24 hrs.
Balsam poplar	UR	66.1	22.7	43.4	32.2	9.0
	BFES	68.3	23.1	45.2	47.8	12.2
Littleleaf linden	UR	58.1	34.4	23.7	15.6	9.0
	BFES	64.9	29.5	35.4	80.6	49.4
Siberian pea tree	UR	60.0	44.3	15.7	15.7	8.7
	BFES	61.2	34.2	27.0	55.1	12.2
Pubescent birch	UR	68.2	34.8	33.4	48.0	17.7
	BFES	70.2	41.0	39.2	69.2	34.2
Green ash	UR	63.2	52.1	11.1	24.0	8.5
	BFES	67.3	31.2	36.1	77.3	47.3
Box elder	UR	82.2	58.8	23.4	63.0	19.6
	BFES	78.5	36.7	41.8	75.7	46.8

The investigation was carried out on a plot in the yard of the Ufa Refinery (UR) and in the arboretum of the Bashkir Forestry Experiment Station (FES). In the UR yard the air is at all times polluted with petroleum gases--hydrocarbons, carbon monoxide, hydrogen sulfide, and, 2-4 times annually, during summer, with relatively weak concentrations of sulfur dioxide. Under these conditions a high resistance was shown by balsam poplar. The leaves of the littleleaf linden and of the Siberian pea tree suffered noticible burns. The pubescent birch, green ash, and box elder were severely stunted (Kulagin, Khanov, 1963). The results in Table 2 show that under these conditions of air pollution the water condition in the poplar leaves changed insignificantly. The bound water content and the water retention capacity of the leaves of the other trees dropped considerably. This can be attributed to their lower gas resistance and to the arrested synthesis of hydrophyllic biocolloids under the influence of the toxic gases. This is also attested by the smallness of their leaves. Leaves thus weakened have a lower drought resistance. However, mass leaf withering and dropping under the influence of drought was observed only during the rooting of new seedlings of which the root system is damaged and cannot draw sufficient water. It is therefore very important to prevent root damage and to avoid drying of the soil during transplanting.

It is, therefore, clear that not all drought-resistant species have also a higher gas resistance; indeed, the only resistant species are those whose leaves have a xeromorphic structure. Toxic gases, when injuring susceptible tree species, affect greatly the water condition of their leaves, lowering the bound water content and their water retention capacity, and thus, their drought resistance as well.

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THE GAS RESISTANCE OF LOCAL AND INTRODUCED ARBOREAL PLANTS UNDER THE CONDITIONS EXISTING IN SVERDLOVSK OBLAST'

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The significant advances in the introduction of arboreal plants into the Central Urals (Mamaev and Petukhova, 1961; Petukhova, 1962) have made it possible to plant greenery in the cities and around industrial establishments by utilizing not only local plants, but also a much richer assortment of acclimatized plants, many of which may often be characterized by much greater decorative properties and gas resistance.

For the purpose of planting trees around industrial plants and populated areas, in which the atmosphere is polluted by SO_2 at a higher concentration than usual (the cities of Krasnouralsk, Kirovgrad, and Revda), an assortment of suitable arboreal plants will be much more limited than the ones available for normal conditions.

The increased gas resistance of many introduced arboreal plants leads to the suggestion that this is in some degree connected with their greater plasticity and adaptability to new ecological conditions of the environment. Indeed, the species that have been successfully acclimatized to the Central Urals do possess high gas resistance: (box elder, Acer negundo; spindle tree, Euonymus europaea; etc.) Arboreal plants that get frostbitten in the winter-spring period (red ash, Fraxinus pennsylvanica; filbert, genus Corylus; barberry, genus Berberis) are less gas-resistant. Excluded from these are Siberian pea tree, Caragana arborescens; and silverberry, Elaeagnus argentea. The first does not get frostbitten under Central Ural conditions, but is weakly resistant to SO_2; the second, on the other hand, freezes during certain individual years, but is a gas-resistant species. The reason for the high resistance of silverberry is due to the fact that both of its leaf surfaces are uniformly covered by umbellate growths of cuticle. As a result of this, the entry of gases into the leaf mesophyll is made difficult.

During 1960, on the basis of a detailed study of the anatomical and physiological characteristics and gas resistance of five arboreal plants their characteristic indices which correlated with gas resistance (Nikolaevskiy, 1964), were revealed. Among these indices can be mentioned the intensity and direction of physiological-biochemical processes in the leaves (photosynthesis, respiration, oxidation-reduction potential, and oxidation-reduction activity) and several indices of the water regimen (free-water content, total water content, and water holding capacity). Gas-resistant species are characterized by decreased intensity of photosynthesis and respiration, decreased oxidation-reduction potential

(ORP) and oxidation-reduction activity (ORA), and a lower content of ascorbic acid. With regard to the water regimen, these same species have a greater content of total and free water and also a greater water-holding capacity.

Among the anatomical indices, there exists a definite connection between gas resistance and the number of stomas per millimeter, the ratio of palisade-tissue thickness to spongy-tissue thickness (h_{pal}/h_{spon}), and the ventilation capacity of the spongy parenchyma according to Ye. I. Knyazeva, 1950). The characteristics of the leaf's anatomical structure that reduce the gas exchange rate contribute to the gas resistance. Only by this is it possible to explain why the leaves of resistant species are characterized by an increased ratio of h_{pal}/h_{spon} and by a decreased ventilation capacity of the spongy parenchyma. On the other hand, the anatomical peculiarities of the leaves correlate well with the intensity and direction of several physiological-biochemical processes therein (photosynthesis, respiration, ORP, ORA).

Of the most practical value in planting greenery around industrial centers is the establishment of an assortment of gas-resistant arboreal plants. Existing data in the literature dealing with this subject are quite contradictory. It is natural that the physical and geographical conditions of one or another region may superimpose their own mark on the resistance of individual species. No doubt many of the recommended lists, which have been compiled on the basis of visual observations, are subjective and inaccurate (Kuntsevich and Turchinskaya, 1947; Ionin and Koltasheva, 1962; and Chernyshev, 1962).

With the purpose of testing the gas resistance of a comprehensive list of arboreal plants (47 deciduous and 6 coniferous species), in 1961 we conducted fumigation on branches in a gas chamber periodically three times a year to determine their susceptibility to injury. The ORP and ORA, ascorbic acid content, quantity of oxidizable substances identified by N. P. Krasinskiy (1950a), total water content of the leaves, and water-holding capacity were determined simultaneously. In addition, on fixed material, the anatomical structure of the leaves was studied in detail.

On the basis of data on the injury to arboreal plants both in the gas chamber and under conditions caused by industrial pollution, the species under study were divided into six groups according to gas resistance and conforming with N. P. Krasinskiy's classification (1950b). A brief characterization of these groups by average data obtained during the growing period is given in Table 1. The indices given for the individual groups of plants are averages derived from the total number of species in each group. The same table lists some statistically developed data: the correlation coefficients r and the index of statistical reliability r/m_r. The cited averages of the physiological-anatomical leaf indices of the individual groups and the statistical characteristics confirm the above conclusions obtained from studying the gas resistance of the five species. A statistically reliable, correlated connection between the intensity of photosynthesis in arboreal plants and the injury to leaves caused by acid gases was obtained. Also, a reliable correlation between the injury to the leaves by gases and the content of ascorbic acid, the amount of oxidizable substances, the total water content, the free-water content, and the water-holding capacity of the leaves was established. The given anatomical indices of the

Table 1

Several anatomical-physiological characteristics of arboreal leaves in relation to their gas resistance.

Grouping of species by gas resistance	Susceptibility to injury according to N. P. Krasinsky (1950b)	Injury in the gas chamber, %	Physiological-biochemical indices of arboreal plant leaves						Leaf water regimen indices				Anatomical indices of leaves		
			Photosynthesis, mg. CO Cal per dm² per hr.	rH_2	Ascorbic acid content, mg.%	Oxidation activity, % ascorbic acid after 10 min.	Iodine-reducing activity, according to Hetry	Quantity of oxidized substances per g. raw weight	Total water content, %	Content of free-water, %	Water retention after 24 hours, %	Concentration of cellular contents, %	Number of stomas per mm²	h_{pal}/h_{spon}	Ventilating capacity of spongy parenchyma, %
1st	Weak	5—10	6,1	13,4	157,0	8,0	395	12,1	70,5	39,4	67	13,0	397	2,10	7,5
3rd	Weak-average	13,5	8,0	16,9	164,9	131,2	446	15,6	65,6	36,4	56,7	17,2	351	1,37	28,0
4th	Average	27,0	8,0	18,2	171,0	149,0	435	24,0	64,8	28,1	53,8	17,2	285	0,93	38,0
5th & 6th	Average - strong and strong	48,0	8,5	18,2	182,0	158,0	446	19,8	64,1	24,6	45,7	16,3	254	0,82	48,0
7th	Very strong	74,0	12,5	18,3	252,0	204,0	615	29,4	64,4	28,6	49,1	16,5	257	0,78	50,0
	r		+0,7	+0,3	+0,46	+0,28	+0,20	+0,54	—0,54	—0,97	—0,35	—	—0,505	—0,47	+0,45
	$\frac{r}{m_r}$		7,4	2,2	3,4	2,5	1,65	7,7	6,8	97	3,2	—	4,2	3,7	3,2

[Editor's note: probably typographical error instead of CO_2.]

leaves (number of pores per millimeter of leaf surface, the ratio of h_{pal}/h_{spon}, and the ventilation capacity of the spongy parenchyma according to Yë. I. Knyazeva, 1950) have a statistically reliable connection with leaf injury caused by gases. Photosynthesis and free-water content are found to have a particularly intimate relationship with leaf damage.

It can be assumed that the absorption of sulfur dioxide by the leaves is directly proportional to the intensity of gas exchange. The existence of a correlated relationship between the anatomical indices of the leaves and leaf damage, and also our confirmation of the role stoma activity plays in gas resistance (Thomas, 1962; Nikolaevskiy, 1964) increases the reliability of this assumption. It is mainly in this that we can see the principle behind the relationship between leaf injury and the intensity of photosynthesis.

The connection revealed between the gas resistance of the arboreal plant leaves and the decreased activity of photosynthesis and respiration, and the derived direction of the physiological-biochemical processes ($rH_2 < 14$) explain quite well, in our opinion, the principle underlying the dependency of injury upon the quantity of oxidizable substances, according to N. P. Krasinskiy (1950a). Since plant organic substances oxidized by potassium permanganate are formed during photosynthesis and respiration, then evidently the quantity of these substances is connected with the intensity and direction of these processes. Actually, box elder, which is resistant to sulfur dioxide, is characterized by a decreased intensity of photosynthesis and respiration and a decreased ORP; at the same time it has a small amount of oxidizable substances per gram of raw weight. European birch, Betula verrucosa, has two times greater photosynthesis, $rH_2 = 17.3$, and there is almost twice as much oxidizable material in its leaves.

In order to substantiate the recommendations on an assortment of species, we studied the gas resistance of the species most widely used in the Central Urals. In the 47 deciduous species used for testing gas resistance, it is of interest to trace the gas resistance and the number of local and introduced species in the various resistance groupings. The relationship of local and introduced arboreal plants according to the particular groups of gas resistance is presented in Table II in absolute and relative indices. Here it is immediately evident that the introduced species predominate in groups 2 and 3. The number of native species increases in proportion to the decrease in gas resistance (groups 6 and 7).

Gas resistance of local and introduced arboreal plants in the Central Urals

Table 2

Groups according to gas resistance	Susceptibility to injury according to N. P. Krasinskiy (1950)	Of the species of arboreal plants studied						Distribution of species by groups, %
		in absolute numbers			in %			
		native	intro-duced	total	native	intro-duced	total	
1st	Very weak	0	0	0	0	0	0	0
2nd	Weak	0	2	2	0	100	100	4,2
3rd	Weak-medium	2	9	11	18	82	100	23,4
4th	Medium	3	11	14	21	79	100	29,8
5th & 6th	Medium strong & strong	2	7	9	22	78	100	19,2
7th	Very strong	4	7	11	36	64	100	23,4
	Total . . .	11	36	47	21	79	100	100

In a similar analysis we experimented with the scale used by N. P. Krasinskiy and Ye. I. Knyazeva (1950). The species therein are divided into three groups: recommended, acceptable, and not recommended. In these groups the ratio of indigenous and introduced species in percentages turned out to be the following:

1st group: native 11, introduced 89%
2nd group: native 28, introduced 72%
3rd group: native 50, introduced 50%.

Our scale (Nikolaevskiy, 1964) had only a 50% congruity with that of N. P. Krasinskiy and Ye. I. Knyazeva (1950). However, under Moscow and Gor'kiy conditions, the introduced arboreal plants also exhibit a greater gas resistance than do the indigenous plants.

The latter may be explained by the great plasticity and adaptability of these species to new ecological conditions, including even air pollution. This is particularly convincingly developed when the gas resistance of the maple species is traced. Box elder is the most successfully acclimatized of the species and is considered quite hardy. In susceptibility to injury it belongs to the second group. Norway maple, Acer platanoides; Tartar maple, A. tataricum; and Amur maple, A.

ginalla, have been acclimatized less successfully in comparison with the first, and in resistance they are relegated to the third, fourth, and sixth groups.

In this connection, in order to make verdant industrial establishments and populated areas having a high degree of air pollution, introduced species such as those that are more gas-resistant should be recommended over any others. Belonging to such species are box elder; red-berried elder, *Sambucus racemosa*; spindle tree; snowberry, *Symphoricarpos racemosus*; silverberry; oleaster, *Elaegnus augustifolia*; "common" elm, species of *Ulmus*; pubescent lilac, *Syringa pubescens*; Canadian poplar, *Populus balsamifera*. From the native species only two can be used: Tartar honeysuckle, *Lonicera tatarica*; and goat or sallow willow, *Salix caprea*.

In cities without a high level of pollution, the assortment can be increased by means of less resistant and native species. Here it is possible to employ even some coniferous species: savin, *Juniperus sabina*; Siberian larch, *Larix siberica*; and Sukachév larch.

Conclusions

1. In the planting of greenery around industrial centers and cities with a significant pollution of the air by acid gases, a wider use is made of introduced arboreal species, as compared with the use of local species. This is due to the fact that the introduced species are not only more ornamental but also are often greater gas resistant.

2. The relatively high gas resistance of a number of introduced species, in comparison with native species, can be explained by their higher plasticity and adaptability to new ecological conditions, including even air pollution.

3. The study of the physiological-biochemical characteristics of arboreal plants and the anatomical-morphological structure of their leaves permitted us to isolate six groups on the basis of gas resistance. Among the resistant arboreal plants in the groups, there predominate introduced species that can also be recommended for landscaping industrial complexes and populated points near them.

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ASSORTMENTS OF GAS-RESISTANT LAWN GRASSES

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From Akad. Nauk SSSR Ural filial. Trudy Inst. Ekologii Rasteniy i Zhivotnyhk. vip. 54, (Sverdlovsk, 1967) p. 91-95.

The planting of industrial regions with green vegetation is essential to public welfare. The selection of plants resistant to gases, while adhering to the rules of agricultural technology, makes it possible to fight the pollution of the surrounding environment.

It is necessary to study plant behavior under conditions of gas pollution in order to select gas-resistant species that are less subject to damage under these conditions.

We conducted investigations concerning the gas resistance of lawn grasses at the Ural aluminum plant in Kamensk-Ural'skiy, Sverdlovsk oblast'. The basic emissions here are fluorine compounds, the maximum concentration of which reaches 0.612 mg. per m^3 of air in the electrolysis sections of the plants.

The purpose of this work was to investigate the physiological reasons for susceptibility to damage of lawn grasses and to select an assortment of resistant grasses for planting lawns in industrial areas under conditions of fluorine pollution. Plant injury has been studied (Krasinskiy, 1950), as well as the intensity of photosynthesis by the L. A. Ivanov method (N. A. Kossovich, 1946) and the water-holding capacity (Nichiporovich, 1926). The volume of free and bound water and also the concentration of cell contents (Gusev, 1960) have been determined.

The tests were conducted during the 1964 growing season with grasses that had been grown for three years near the electrolysis plant (the test) and in a residential area (the control). Analogous investigations were conducted on one-and two-year-old plants (Kazantseva, 1963).

Photosynthesis and the water regimen were studied in depth in meadow fescue, *Festuca pratensis*; red fescue, *F. rubra*; Kentucky bluegrass, *Poa pratensis*; red top, *Agrostus alba*; and timothy grass, *Pheleum pratense*. Grass damage was observed in early spring when the leaves were appearing. In this period there was a burn on the tips of the leaves, then spotting and blotching appeared. The burn gradually spread to the base of the leaves, which brought about their demise. With the growth of the above-ground mass, the damage increases and reaches a peak toward the end of the season (in August).

Figure 1 shows grass damage during the growing period. The smallest percentage of damage (5%) in the spring of 1964 was observed on meadow fescue, red fescue, and Kentucky bluegrass. The greatest damage was found on red top and "regneria" (a species of Roegneria - related to wheatgrass, *Agropyron*), (25%), awnless bromegrass, *Bromus inermis*; and timothy grass (30%). Toward the end of the season, damage to meadow fescue, Kentucky bluegrass, and red fescue was 35 to 40%, and to awnless bromegrass, red top, "regneria," and timothy grass up to 50-60%. Hence, grasses that are not resistant to fluorine have a percentage of damage almost twice that of those that are more resistant.

Average data on grass damage in 1964 are shown in Table 1.

Lawn grasses can be divided into two groups in terms of leaf damage: slightly damaged (meadow fescue, red fescue, Kentucky bluegrass) and greatly damaged (red top, "regneria," awnless bromegrass, timothy grass). The injuries are an external reflection of the effect of toxic substances and appear on plants mainly during the photosynthesis process (Ivanov, 1936). A number of authors (Thomas and Hill, 1937; Fortunatov, 1958) have dealt with the effect of fluorine and sulfur dioxide on plant photosynthesis. The authors' investigation into lawn grass photosynthesis showed that the intensity of photosynthesis varied among the species studied. Figure 2 presents the photosynthesis of lawn grasses for a growing period. From these data it is evident that the greatest intensity of photosynthesis during summer is found in red top.

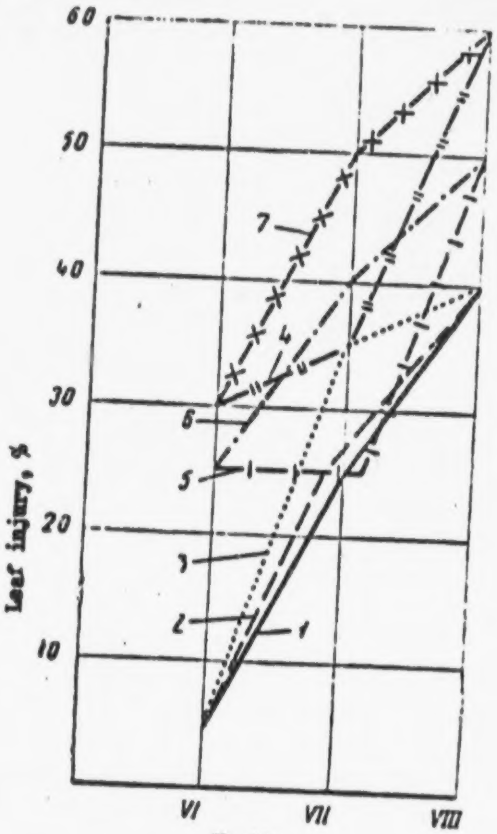

Fig. 1. Grass damage during growing period of 1964.

1-meadow fescue; 2-red fescue; 3-Kentucky bluegrass; 4- awnless bromegrass; 5-red top; 6-"regneria;" 7-timothy grass.

Table 1

Dependence of damage to lawn grasses on photosynthesis (average data for 1964)

Plant	Damage %	Intensity of photosynthesis mg. CO_2 per 1 dm^2 per hour
Meadow fescue	23	44.9
Red fescue	23	39.6
Kentucky bluegrass	26	49.9
Red top	33	81.1
Timothy grass	46	43.5
"Regneria"	38	----
Awnless bromegrass	40	----

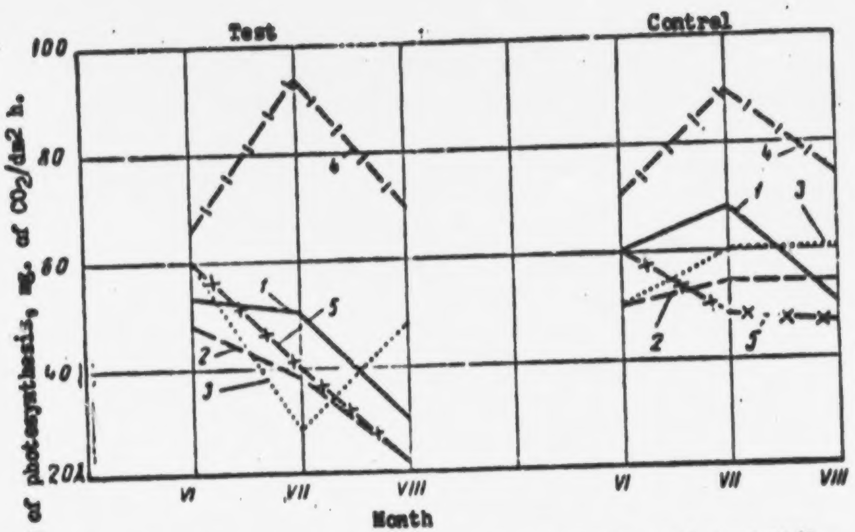

Fig. 2. Photosynthesis of grasses for a growth period of 1964. 1-meadow fescue; 2-red fescue; 3-Kentucky bluegrass; 4-red top; 5-timothy grass.

If these average monthly data are compared in terms of photosynthesis, it is evident that in the most damaged grass -- red top -- the intensity of photosynthesis was two times greater than in the less damaged meadow fescue, red fescue, and Kentucky bluegrass. Timothy grass behaved rather strangely. This grass is usually severely damaged by fluorine from July on, but data on photosynthesis were low in comparison with the heavily damaged red top. Evidently, this can be explained by the anatomical and physiological-biochemical peculiarities of timothy grass.

From the data obtained it follows that slightly damaged lawn grasses have a lesser intensity of photosynthesis than those that are severely damaged (with the exception of timothy grass). This principle can be explained by the fact that grasses with lesser energy of photosynthesis are characterized by less active enzyme systems, and this in turn lowers gas exchange and decreases the accumulation of fluorine by leaf tissue, as a result of which they are damaged to a lesser degree. The opposite is observed in severely damaged grasses. This connection was established by investigations of woody plants conducted by V. S. Nikolaevskiy (1963). Photosynthesis intensity in grasses grown in a gas polluted zone is lower than in a residential area by 40% to 10% (see Figure 2).

Consequently, under the effect of fluorine compounds, the photosynthesis of lawn grasses is depressed as a function of the worsening of the growing conditions and the daylight factor and of the accumulation of fluorine in the plants. Average photosynthesis and data of injury over a one-year period for three-year-old grasses are presented in Table 1, from which the same connection can be seen between the intensity of photosynthesis and susceptibility to damage, as from average monthly indices. Red top, very heavily damaged (33%), has the highest intensity of photosynthesis (81.1 mg. CO_2). Timothy grass has the highest degree of damage (46%) and a low intensity of photosynthesis (43.5 mg. CO_2). This is explained by its specific characteristics.

The water regimen of the plants is a part of the overall process of plant metabolism (Gusev, 1960). The character of a water regimen can facilitate an increase in the hardiness of plants in proportion to unfavorable conditions. The differences of water regimens are determined by the specificity of proteins and metabolism in plants. The water-holding capacity of leaves, according to N. A. Maksimov (1952) and other investigators, can serve as an index of plant stability.

Table 2

Water-holding capacity of leaves of lawn-grasses, %
(average monthly data)

Plant	Polluted Area			Control		
	June	July	August	June	July	August
Meadow fescue	12.0	12.0	6.0	12.0	12.3	10.0
Red fescue	8.0	9.0	6.0	9.0	10.5	6.0
Kentucky bluegrass	7.0	8.0	7.0	8.0	11.0	11.0
Red top	6.0	7.5	4.0	7.0	12.0	8.0

Investigations of the water regimen of three-year-old grasses showed that the water-holding capacity of their leaves after 24 hours without water was not the same (Table 2). Red top, severely damaged by fluorine, had a lower water-holding capacity, and the less damaged (meadow fescue, red fescue, Kentucky bluegrass) had a high water-holding capacity. The tabulated data show that in a controlled sector the water-holding capcity of grasses is greater than in plants in an industrial zone:

Table 3

Quantity of bound and free water in leaves of lawn grasses, %

Plant	Polluted Area				Control			
	Bound Water		Free Water		Bound Water		Free Water	
	July	August	July	August	July	August	July	August
Meadow fescue	63.0	25.0	13.5	47.0	18.0	34.0	62.0	47.0
Red fescue	59.0	30.0	13.0	40.0	48.0	34.0	31.0	41.0
Kentucky bluegrass	54.0	23.0	16.0	51.0	32.0	26.0	45.0	50.0
Red top	66.0	26.0	12.0	40.0	39.0	63.0	38.0	12.0
Timothy grass	65.0	36.0	10.0	40.0	47.0	48.0	29.0	26.0

While determining the water forms in lawn grasses (Table 3), it turned out that meadow fesuce, Kentucky bluegrass, and red fescue had more free water than the heavily damaged red top and timothy grass. A more pronounced difference in the volume of free water was noted in July 1964: 13.5% for meadow fescue, 16% for Kentucky bluegrass, 13% for red fescue, 12% for red top, and 10% for timothy grass. The quantity of free water in grasses grown in a residential district was greater than in grasses from an industrial area. The tabulated data show that in the severely damaged grasses, red top and timothy, there is a greater quantity of bound water than in less damaged ones: meadow fescue, Kentucky bluegrass, and red fescue. In determining the concentration of cell contents, it was learned that there is no substantial difference between the data for different grasses.

A comparison of water regimen indices for 1964 with grass injury (Table 4) shows that there is a connection between damage and both water-holding capacity, and water forms. Less damaged grasses are characterized by a higher water-holding capacity and greater volume of free water; the opposite is observed for severely damaged grasses.

Table 4

Water regimen indices for grass leaves as functions of their gas resistance, % (average data)

Plant	Water-holding capacity	Free Water	Bound Water	Juice Concentration	Damage
Meadow fescue	10.0	30.0	44.0	5.50	23
Red fescue	7.6	26.5	44.5	7.50	23
Kentucky bluegrass	7.3	33.5	38.8	5.75	26
Red top	5.8	26.0	46.0	5.50	33
Awnless bromegrass	7.0	-	-	-	40

Conclusions

1. Fluorine compounds damage lawn grasses, decrease photosynthesis, water-holding capacity, and the quantity of free water.

2. Slightly damaged species of grass have a lower intensity of photosynthesis, greater water-holding capacity, and a greater quantity of free water. The opposite is characteristic for severely damaged species.

3. For planting greenery in industrial sectors with fluorine emissions, the following lawn grasses can be recommended:
   a) for sectors with severe pollution: meadow fescue, red fescue, and Kentucky bluegrass;
   b) for sectors with little pollution: "regneria," Awnless bromegrass, red top, and timothy grass.

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RESISTANCE OF SOME GRASSES TO FLUORINE

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From Akad. Nauk SSSR Ural. Filial. Komis. po Okhrane Prirody. Rastitel' nost' i promyshlennye zagryazneniya. Okhrana prirody na Urale. V (Sverdlovsk, 1966) p. 45-47.

Compared with sulfur dioxide, the fluorine compounds are appreciably more toxic. One-tenth parts of fluorine per thousand million parts of air will cause injury (Thomas, 1962). Fluorine concentrates on the periphery of broad leaves and on the tips of narrow ones. Gas injury destroys the pulp of the leaf and the chlorophyll, which is endowed with photodynamic properties and controls oxidation. Thus, the normal life function of the plant is damaged.

Recovery of the leaf after fluorine injury is slower than after a sulfur dioxide injury. In 1962 we set up experiments for the study of gas-resistance to fluorine of some grasses for the purpose of selecting a gas-resistant assortment. The experiments were set up at the Kamensk-Ural'skiy aluminum plant in the Sverdlovsk region.

During the production of aluminum in the electrolyzer shops, fluorine compounds (hydrogen fluoride and fluorides) are given off. The maximum concentration of fluorine within a radius of 1 km. from the source of pollution is 0.307 mg./m.^{3} and of SO_2 -- 0.37 mg./m.^{3}. Plants growing on the territory of the mill are injured mostly by the fluorine discharged in an adventitious manner, such as seepage through windows and cracks of the electrolysis shop. Therefore, the experimental plots were located near the electrolysis shop where the concentration of fluorine was 0.612 mg./m.^{3} .

As control, similar plots were located in Sotsgorod, at a distance of 2000 m. from the source of pollution; the fluorine concentration there was 0.05 mg./m.^{3} . The grass was sown in fertile soil and the species planted were the following: meadow fescue, red fescue, Kentucky bluegrass, perennial ryegrass, meadow foxtail, timothy grass, redtop, awnless bromegrass, meadow brome, and roegneria. Detailed studies were undertaken with redtop and meadow fescue. The study of both plots involved direct observations and consideration of physiological indices. From the very beginning of the experiment observations were recorded regarding damage to the leaves of the cereals (in percentage of leaf area -- by the N. P. Krasinskiy method); the plant height was recorded (in cm.) in relation to the fluorine concentration; the water retention ability of the leaves was studied by weighing at predetermined time intervals (by the A. A. Nichiporovich method, 1926); the quantity of oxidizable substances (total, water-insoluble, and water-soluble substances) was determined by the N. P. Krasinskiy method. The grasses were studied in June, July, and August during the first and second year after sowing. The development stages of the plant, fluorine concentration, and other factors were considered. In order to attain greater clarification, additional experiments were conducted in gas chambers. The plants were fumigated for 8 hours with fluorine in a concentration of 0.8 and 0.03 mg./m.^{3}. The water retention capacity was determined by the A. A. Nichiporovich method immediately following fumigation.

Leaf injury was observed 3-4 weeks after seeding, and more severe damage occurred toward the end of summer, in August. Burns appeared on the leaves in the form of brown dots, spots, and streaks. The burn spread toward the base of the leaf. The lower leaves died of injury. The redtop was injured most, while the meadow fescue suffered to a lesser extent (% of leaf area):

	First Year			Second Year	
	6/25	7/26	8/25	5/15	8/25
Meadow fescue	10	20	30	5	25-30
Redtop	10	30	50	20	50

At the end of the growing period the injury to the meadow foxtail, awnless bromegrass, meadow brome, and roegneria was 50-60%. The least injury (25-35%) was noted in Kentucky bluegrass and red fescue. Compared with the control plants, the plants grown on the plot at the aluminum mill were smaller (cm.):

	Experiment			Control		
	6/26	7/25	8/25	6/25	7/25	8/25
Meadow fescue	12	15	25	15	25	35
Redtop	8	13	19	12	22	29

The redtop on the industrial plot began to head in July; this was not the case with the control plant. Consequently, a greater gas concentration accelerates the process of development of certain grasses.

A study of the water retention capacity in grasses subjected to the action of fluorine on the industrial plot revealed an interconnection between the water retention capacity and gas resistance. The species having the greater water retention capacity were least injured by the gases. The water retention capacity of the meadow fescue was greater than that of the redtop. The water retention capacity of grasses grown on the industrial plot was lower than that of the control plants (%).

	Experiment			Control
Month:	VI	VII	VIII	VIII
Meadow fescue	3.6	25	23	30
Redtop	1.6	11	9	18

When meadow fescue and redtop were fumigated with fluorine in gas chambers, the water retention capacity of the former remained higher than that of redtop. An increase in the concentration of fluorine (0.8 mg./m.^{3}) acts as a depressant, and the water retention capacity of the plant at this concentration of fluorine was lower than at 0.03 mg./m.^{3}. The experiments in fumigation chambers confirmed the interdependence of the water retention capacity and fluorine concentration as well as the specificity of plant species' reaction to an 8 hour exposure to fumigation (%):

	Fluorine concentration, mg./m.^{3}		Control
	0.8	0.03	
Meadow fescue	8.8	21	25
Redtop	0.5	3	5

Determination of oxidizable substances in the cell content showed that meadow fescue has the least amount of it, whereas redtop has the largest. Toward the end of the season (August) the quantity of oxidizable substances in grasses diminishes; more of it was in the control plants than in the plants grown on the industrial plot (see following table).

Oxidizability of cell content in first year grasses in relation to fluorine concentration, ml. of 0.1 N $KMnO_4$ per 1 g. of raw sample.

Oxidizable substances	Meadow fescue			Redtop		
	June	July	August	June	July	August
Fluorine concentration 0.612 mg./m.^{3}						
Water insoluble	3	6.5	3	7.5	7.5	4
Water soluble	8.5	4.0	3.5	10	5	6
Total	11.5	10.5	6.5	17.5	12.5	10
Control						
Water insoluble	-	--	3.5	-	-	6.5
Water soluble	-	--	6.0	-	-	6.0
Total	-	-	9.5	-	-	12.5

Consequently, fluorine compounds damage the leaves of grasses, stunt their growth, lower their water retention capacity, and change the oxidizability of their cell content. Plant species with the largest water retention capacity and lowest oxidizability are more resistant to fluorine.

The grasses less affected by fluorine, namely, meadow fescue, red fescue, and Kentucky bluegrass are recommended as suitable for planting in the industrial areas having the highest concentration of fluorine.

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MAKING A CITY VERDANT

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From Peredovoy Opyt -- Organizatsiya Zdravookhraneniya.
Sokolovskiy, M. S., Zh. L. Gabinova, B. V. Popov, and L. F. Kachor.
"Sanitarnaya Okhrana Atmosfernogo Vozdukha Moskvy"
(Iz opyta raboty Sanitarno-epidemiologichesckoi stantsii goroda Moskvy)
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It is well known that greenery plays an important role in improving the microclimate and the hygienic conditions of urban areas. The popular saying has it that green plantings are "oxygen factories" and "the lungs of the city".

In the course of their life processes, plants absorb carbon dioxide and release oxygen. The leaves of trees and shrubs vaporize moisture, thereby absorbing considerable quantities of heat. This phenomenon and the fact that treetops retard and block direct sunrays cause a temperature differential of 3-5° C. in planted areas as compared with bare areas.

Green plantings also reduce the velocity of wind, which is particularly noticeable in summer when the air in a forest or park is calm. This is the very reason for planting forest belts in the steppe as protection against the adverse effects of dry winds. As the velocity of air movement decreases, the suspended dust contained in the air begins to settle down and the air becomes clearer. It has been established that in parks and gardens located near industrial enterprises, the dust content in the air is reduced by 40% or better, as compared with open spaces.

The dust settling out from the air is retained on leaves, trunks, branches and twigs; the quantity of dust retained by leaves varies with the tree species. Thus, elm leaves, having a rough surface, retain 6 times as much dust as the smooth leaves of poplar, linden, and aspen.

Dust retained on leaves in mg./m^2 of surface is given by the following values: elm, 3.39; lilac, 1.61; linden, 1.32; maple, 1.05; and poplar, 0.55.

Considering the dust-protective effect of greenery, a suitable selection of trees and their proper placement can bring about a considerable reduction of dust in air over the residential areas. Green plantings are also important in reducing city noises. Crowns of broad-leaf tree species absorb up to 20% of incident sonic energy, and deflect and scatter another 74%. It has been established that up to two meters from the surface noise intensity on a street of multi-storied buildings and having no trees is 5 times higher than on a street bordered with trees along the sidewalk. In gardens and parks, trees planted in separate individual groups reduce noise more effectively than trees planted in rows. Most effective in reducing noise are a combination of low growing trees having wide crowns and plantings of shrubery.

Until lately, vacant areas in Moscow were planted solidly, setting out on the perimeter thick live green hedges consisting of two or three rows of shrubs and trees of varying height. A different approach is now widely accepted in which a prominent place is given also to lawns. This landscaping style is pleasing to the eye, creating a perspective of plantings of various heights and levels arranged on a greensward; they provide a simplicity of form in place of the standard geometrically rigid configuration. Green plantings inside city blocks are of great psychological and hygienic value. Man spends part of his life amid the intrablock plantings, which are in a way an extension of his living quarters, thereby bringing man and nature closer together.

It is considered best to transplant trees at the age of 8-11 years. In order to allow trees to become well-established, they should be transplanted 5 years before the start of housing construction in an area. Actually, however, intrablock plantings are delayed to the last moment and undertaken only before the housing is open for occupancy. Quite frequently, the landscaping is done without previous planning and without participation of the designers of the housing development. Furthermore, no representative of the city landscaping administration participates in accepting the finished housing project.

Regretably, the tendency to locate new housing in the most economical way frequently results in encroaching upon the area designated for home gardens. The accepted principle that one third of city area should be devoted to green plantings is not always followed. The landscaping is frequently conventional and the work not always of good quality. According to official data, the loss of trees in new plantings is 30-40%.

Poor maintenance of the new plantings also contributes to their loss. Rotary snow plows and the use of salt for cleaning sidewalks affect adversely green plantings. Snow sliding off the roofs frequently deforms tree crowns.

The city administration and the architectural and planning organizations forget that a multi-story building can nowadays be erected within 2-3 months, whereas it takes 15 years for the development of a full grown shade tree. Frequently, when a plot is designated for construction, single trees and even entire groves are cut down. Thus, according to the data of the Moscow forest-park administration, 80,000 trees and 180,000 shrubs were cut down in the last 5 years in connection with building activity. This happens because of lax city building codes. Here, it is appropriate to quote a remark in a Swedish journal, which speaks of a single adult tree that was to have been destroyed on a building plot. To save it, the architectural council decided to build a two-wing rather than a three-wing house.

In cities the growth of the population outstrips the rate of green plantings. Thus, the green area per city dweller does not increase but rather diminishes.

A similar situation, although to a lesser extent, prevails also in Moscow, notwithstanding the increase of green areas from year to year. Thus, for example, in 1959 an area of 380 ha. was planted, in 1960 an area of 480 ha. was planted, in 1961 the area planted was 655 ha., and in 1962 the area of 707 ha. was planted. At the present time, the total land area of Moscow consists of 87.5 thousand ha. of which 18.7 thousand ha. are planted to greenery. Great losses to new plantings are due to poor maintenance and lack of protection. The community can and should provide a greater help in this endeavor. True, that during the autumn and spring planting, the community carries out a great deal of work. The community contributed in 1959 1.3 million man-days for green plantings in Moscow. In 1960, it donated 2 million; in 1961, 3.1 million; and in 1962, 3.7 million man-days.

However, the community is little attracted to the subsequent care and protection of the plantings. Thus, in Sverdlovsk a "green patrol" numbering 30,000 people (mostly children) was established to protect green plantings. Single trees were assigned to individuals to take care of and to protect them. The participation of school children in such work is essential, and yet, the educational work to instill in children the love of nature is sadly lacking. Children should be educated in the proper attitude to natural resources. Such an attitude to nature must become an integral part of the moral code of the builders of communism.

Up to the Great October Socialist Revolution, there were 833 ha. of parkland for public use within the city limits of Moscow of that period. This amounted to 9.1% of the total city area which consisted then of 9150 ha. The per capita park area at that time was 5.9 m.^{2} (Sovremennoe khozyaystvo Moskvy, 1913).

At the present, the green planted area of the city is 18,700 ha. or 20% of the total city area, and the per capita area is 18.5 m.^{2} . The distribution of greenery in Moscow is unequal. In the center of the city, within the Sadovoe Kol'tso, the per capita area is 0.84 m.^{2}; in the area between the Sadovoe Kol'tso and the circumferential railroad, 4.56 m.^{2}; and in the area between the circumferential railroad and the beltway, 8 m.^{2} .

Nor is the greenery distributed evenly among the city districts. Thus, in the Bauman, Kirov, Frunze, and Sverdlov districts the per capita green area of all kinds is only 2.5 m.^{2}, whereas in the Kuybyshev, Pervomayskiy, Dzerzhinskiy, and Kievskiy districts it comes to 62 m.^{2} . It is planned to expand the green plantings of all kinds in 1980 to an area of 50 m.^{2} per each inhabitant of Moscow.

At the present time the green plantings in the city consist of 56 species of which the birch makes up 24%; the linden, 23%; the poplar, 10%; the pine, 9%; and the spruce, 1%.

All the large parks are located beyond the Sadvoe Kol'tso and are concentrated mainly in the northeastern part of the city. In that part of the city are found the Pokrovskiy-Streshnev Park, 140 ha.; Ostankino Park, 74 ha.; Sokol'niki Park with its experimental forest resort, 700 ha.; and the Izmaylov Park, 1180 ha. In the southwestern part of the city, the parks are concentrated predominantly along the Moskva river: the Central Park of Culture and Rest, 105 ha.; Leninskie Gory Park, 85 ha.; Fili-Kuntsev Park, 97 ha.; and the Khoroshev Serebryanyi Bor, 92 ha. As a rule, the parks are well maintained in the central part. Because of considerable air pollution and many visitors, the trees in the parks are weak and diseased; they are also infested by pests because of the absence of birds.

The average forest area per inhabitant of Greater Moscow is 92 m.^{2} or, subtracting the area closed to the public, 89.4 m.^{2}. Most of the forests are mixed. Limited areas of deciduous forests in the Moscow district are formed in the Ul'yanov section of the Moscow oblast' and of conifers, in the Balashikha section. Among the conifers the pine predominates and among the deciduous, the birch. The conditions of the forest vary: along with the healthy and robust forest-parks (Krasnogorsk, Cherkizov) there are weak ones found particularly near industrial enterprises and in areas most frequented by people. The basis of the city's greenery are the large green plantings represented by the municipal parks. These are distributed evenly in accordance with the planned zones between the main traffic arteries.

The general municipal parks merge directly into forest-parks which, in certain parts of the city, penetrate into it; otherwise they are connected to the city by avenues, boulevards, and green strips.

New extensive plantings are projected in order to eliminate the existing imbalance in the distribution of general city parks. The parks in the city districts are a link in the greening of Moscow. They should be evenly distributed throughout the city. The existing municipal parks (Pokrovskoe-Glebovo, part of Izmaylov, Kuskovo and others) will henceforth serve city districts.

Of the green plantings designed for general use the ones nearest to the inhabitants are the neighborhood park-gardens, the so-called "micro-regional gardens". The system of city greenery comprises various plantings such as those of courtyards of houses, recreational facilities, schools, hospitals and medical establishments, around industrial and warehouse buildings, on city thoroughfares as well as those of the sanitary shelter belts of industrial areas and other special purpose greenery. Plans are made to establish municipal parks in the cities and towns of the forest-park shelter belt. It is further planned to enlarge and provide facilities in the parks of Lytkarino, Balashikha, Lyubertsy, and Mytishchi. Part of the planted area in the forest-park belt will be designated as game and bird preserves. Along with their use for educational purposes, they are needed for combatting forest pests that increased greatly because of the decrease of the useful fauna (i.e., decrease of the pests' natural enemies seemingly as a result of air pollution).

In order to determine the effects of gases on tree plantings under the environmental conditions of Moscow and those of the forest-park protective belt, the department of air hygiene carried out in 1959-1960 observations in the Izmaylov Park of Culture and Rest, and in 1961-1962 in the forest-parks of the Moscow suburbs (in the area known as "Podmoskov'e").

The conifers (pine, spruce, and fir) were most susceptible to the action of atmospheric pollutants, and particularly to that of acid gases. Therefore, an investigation was carried out concerning the effect of sulfur dioxide on the coniferous plantings of Moscow and Moscow suburbs (Podmoskov'e) -- SO_2 having a particularly adverse effect on the conifers.

Sulfur dioxide, a component of smoke gases, is discharged into the air all over Moscow in larger or lesser concentrations, depending on the type, quantity, quality, and method of fuel combustion.

High concentrations of acid gases in the air cause great damage to vegetation by producing burns. Prolonged action of low concentrations cause chronic damage to the physiological and biochemical processes of plants.

The destruction of old conifer stands is intimately connected with the growth of the city and its encroachment on the surrounding forest areas.

The degree of air pollution of individual districts in large industrial cities, among them Moscow, depends not only on the number of industrial enterprises and the volume of their discharges but also on the topography of the district and the location of the enterprises in relation to the prevailing winds, height of smoke stacks, and so on.

In Moscow, withering of pines occurs in Sokolniki and Izmaylov parks, in the Pokrovskiy-Streshnev forest, in the experimental forest resort of the K. A. Timiryazev Agricultural Academy, and in other places. A study of the injurious effect of acid gases on conifers in the Izmaylov park was carried out in 1959 by the division of air hygiene of the Sanitary-Epidemiological Station of Moscow along with the 5th Aerial Forest Photo-Survey Expedition of the All-Union "Lesprojekt" Association.

In 1958, the Izmaylov Park located in the eastern part of the Pervomayskiy district of Moscow stretched over an area of 1180 ha., 709 of which were solidly covered by forest. The rich, natural resources of this park made possible there the existance of a diversified and a highly valuable assortment of trees -- an assortment quite rare in the Moscow environs. Up to the thirties, the upper story of the forest produced 1 and 1-a grades of timber of prime age (an average of 108 years) with a density rule of 0.5. The second or middle story was made up of broadleaf trees, predominantly linden (50-70 years old), as well as oak, Norway maple, elm, and, in certain areas, birch.

The undergrowth, or lowest story, consisted of thickets of hazelnuts, viburnum, elder, honeysuckle or woodbine, and others. The vitality of the plants was high and no withering or weakening of trees could be seen.

In the early thirties, the city started encroaching on the park area from the southwestern side, i.e., from the side of the prevailing winds. Housing came nearer, large industrial enterprises sprung up near the park and close to it. These caused air pollution over the park by acid smoke gases. It was then that the withering of pines in the western part of the park set in. Coinciding with the appearance of industrial enterprises in the Pervomayskiy and adjacent districts, particularly with the construction of a thermal power station with a 126 m. high smokestack along with other power stations and industrial enterprises, and with the corresponding growth of automotive traffic along the roads surrounding the park, the withering of pines grew at an alarming rate and spread over ever larger areas from the southwest to the northeast, in the direction of the prevailing winds. At the present, pines are to be found only in certain spots of several northeast sections of the park. Figure 20 shows the decline in the number of pines.

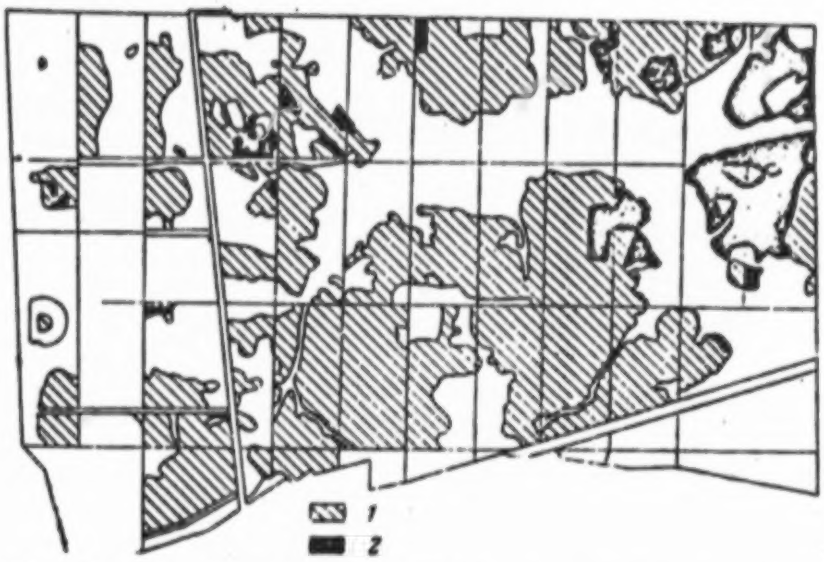

Fig. 20. Plan of Izmaylov Park showing the course and nature of changes in pine stands.

1 - area covered with pine trees in 1946; 2 - ditto in 1959.

The visible signs of pine withering are: dried-up crowns, thinning of treetops, loss of normal color by needles, their shortened lifespan, and a large number of stunted barren cones. Observations showed that the lifespan of pine needles does not exceed 2 years, and in most cases lasts only 1 year. With the shortened lifespan, the increments in diameter and height declined.

Table 7 shows the diminishing decennial increment in height of pine trees from 1870 on, determined in 1959 in one of the park areas.

It can also be seen in Table 7 that there is a clear break in the course of the height of pine growth occurring in 1930, and similar changes with time up to 1930 and after 1930, are revealed by the analysis of increments of tree diameters as well as in the nature of seed production of the pines within the area of the park.

Table 7

Increment in height of pine trees

Age of trees, years	Meters of height increment per decades, m.	
	1870 - 1929	1930 - 1959
112	3.8	0.4
85	4.6	0.6
79	4.6	1.3

On the whole, air pollution by sulfur dioxide stunts tree growth and disturbs seed production of trees. Gradually, the pines withered and died. This happened mostly to older trees and to pines of single stage structure. Equally severely affected by sulfur dioxide was the spruce and fir, i.e., species with perennial coniferous needles. In the area of the Izmaylov park pine stands of all ages were damaged, regardless of the multistage structure of the forest.

In the 1959 inspection no widespread infestations by insects and disease were found.

At the present, the pine in the upper story is replaced by broadleaf trees, primarily linden.

Generally, deciduous trees are more gas-resistant than conifers.

The rapid replacement of pine stands by deciduous trees in the last 27 years is seen from the records of the forest administration for 1931 and 1958, Table 8.

Table 8

Forest-park area distribution by species

Species	1931		1958	
	Area, ha.	%	Area, ha.	%
Pine.	580	77.4	74	10.4
Spruce	45	6.0	1	0.1
Fir	[illegible]	[illegible]		
Larch	4	0.4	22	3.1
Oak..	---	----	89	12.5
Linden.	22	2.0	288	40.9
Birch	60	8.0	154	21.7
Aspen	21	2.8	29	4.0
Other	12	2.5	52	7.3

Thus, in the last 27 years, the area in the park occupied by pines shrank from 580 to 74 ha., while spruce and fir disappeared entirely. Simultaneously, there is a sharp increase in the area occupied by linden, birch, and oak stands, as well as by other deciduous species.

The average age of pines decreased to 90 years, according to the forest administration data (1958).

At the present, the basic component of the park are stands of linden with an average age of 74 years. The growing of linden is not recommended because of its low smoke resistance. According to the 1958 data of the forest management, the linden stands everywhere in the park show signs of weakening, and in most of the park area are of second-rate vitality.

Up to recently, air pollutants affected mostly the crown-tops of pine stands. After the destruction of the pines, the toxic substances in the air attacked the stands of linden, particularly the peripheral parts of the crowns of the trees. This explains the weakening in growth and vigor of the park linden.

To understand better the effect of air pollution on pine stands, a study was carried out in the forest resort of the K. A. Timryazev Academy of Agriculture.

Observations were made of the local soil conditions, forest valuation and the kind of air pollution.

The forest resort embraces an area of 248.7 ha. The vegetation of this area is made up predominantly of pines with an average age of 76 years. Here, like in the Izmaylov Park, widespread withering of the pines started in the thirties, with the approach of the city from the southwest. However, the broadleaf trees show no signs of weakening. True, there are no large-scale industrial enterprises near the resort. The sources of air pollution are essentially the railroad, house heating plants, and automotive transport. The visible signs of poisoning are the same as in the pine stands of the Izmaylov Park. But here, the drying up of pines did not spread over the entire area; the pines in the forest resort died only in a wide strip at its southwestern edge and in narrow strips along asphalt covered highways. In the center of the resort and on its northern boundary the pines survived in good shape alone or mixed with deciduous species.

Records of air study carried out at the hospital in the Izmaylov Park for 1955-1961 show strong air pollution with sulfur dioxide throughout the year, Table 9.

Table 9

Air Pollution by sulfur dioxide in Izmaylov Park

Month	Maximal single concentration, mg./m^3				
	1955	1956	1957	1958	1959
April	1.25	1.20	1.58	2.45	0.9
May	0.09	1.62	1.60	0.80	0.34
June.	0.70	1.64	0.90	0.54	0.35
July.	0.73	1.91	0.73	0.63	0.29
August.	1.47	0.54	0.89	0.86	0.18

A decrease in the concentration of sulfur dioxide with the passage of years is attributable to replacement in the industrial enterprises and in thermal power station No. 11 of the Moscow coal by the low-sulfur Don coal, and still later by gas. This change reduced the volume of sulfur dioxide vented into the air. In 1952, the thermal power station No. 11 discharged into the atmosphere 72,000 tons of sulfur dioxide, in 1959, this was reduced to 25,000 tons, thus a reduction to almost one-third.

The data in Table 9 refer to the growing season. In winter, autumn and early spring, when the heating plants consume larger quantities of fuel, the concentration of sulfur dioxide in the atmosphere was 2-3 times higher than the ones given in the Table.

Such quantities of sulfur dioxide burn the needles of conifers completely and irreversibly. The established maximum single concentration of sulfur dioxide in the air is 0.5 mg./m.^{3} .

There is no general agreement concerning the tolerance limits of sulfur dioxide by plants. A spruce withstands sulfur dioxide concentrations from 0.09 to 0.2 mg./m.^{3} without noticeable injury. In 1955 the number of determinations showing an excess over the allowable maximum concentration of sulfur dioxide (0.5 mg./m.^{3})--which in itself is considerably higher than tolerated by spruce--amounted to 27.1%. In 1956, the number rose to 28.2%; in 1957, to 29.2%; in 1958, it dropped to 18.7%; in 1959, to 6%; in 1960, to 4.5%; and in 1961, to 3.8%.

The sulfur dioxide content in the atmosphere of the forest resort of the K. A. Timiryazev Academy of Agriculture differs greatly from the above. Spring and summer observations in 1955 showed a sulfur dioxide concentration in most of this area of 0.07 to 0.19 mg./m.^{3}. Only in the southwest sections, near the railroad line and apartment houses, the sulfur dioxide concentration reached 0.23-0.36 mg./m.^{3} . Nowhere on the territory of the resort did the concentration attain the permissible limits of 0.5 mg./m.^{3}. Maximum one-time concentrations did not exceed 0.4 mg./m^3.

Thus, the difference in concentration of sulfur dioxide in the air over the Izmaylov Park and over the forest resort is quite significant. It was reflected in the degree of toxic effect and in the damage done to the trees in these two heavily planted areas.

The above data on air pollution lead to the conclusion that in order to preserve and restore the city and suburban forest-park stands of Moscow, the concentration of sulfur dioxide in the air should not exceed 0.10-0.20 mg./m.^{3}.

The effect of gases on conifer stands is demonstrated in the Izmaylov Park. All other conditions being equal (soil moisture, excessive load of visitors, stamping out of soil cover, poor maintenance, and so on), the larch is doing quite well. The area occupied by larch increased 5.5 times and the one occupied by linden, 13 times. However, the evergreen conifers perished. Another investigation of the effect of air pollution by industrial discharges on conifers was undertaken by the management of suburban Moscow forest-parks.

In 1961-1962, the forestry laboratory in cooperation with the department of atmospheric air hygiene of the Sanitary-Epidemiological Station of Moscow carried out a study on the condition of tree stands under air pollution in an air-polluted environment of the forest-park belt of Moscow. It was done under the direction of the biologist, A. P. Shcherbakov (M.B.S.).

The major objective of this investigation was to prove experimentally the adverse effect of gas and smoke pollutants, vented by industrial enterprises of the city, on tree stands of the green belt.

The prevailing winds in suburban Moscow -- Podmoskov'e -- are from the west to east and from southwest to northeast. Therefore, for the purpose of this investigation, the areas selected comprised the forest-park enclaves in the eastern part of the Moscow forest-park shelter belt: the Podmoskov'e, Mytishchi, Balashikha, and Kuchino forest preserves. The control areas for this investigation consisted of the forest preserves in the western part of the shelter belt, in the Zvenigorod district: Khlyupino, Sharapovo, Stepanovo and Nikolina Gora.

In each of the selected areas were chosen 3 plots of 0.5 ha. each, with appropriate stands of pine and spruce in barling stage (15-20 years old) and maturing stage (60-80 years old) growing in soil with a similar grass cover. The entire experimental work was conducted in these areas.

Laboratory studies of the atmospheric air of the plots under investigation showed that in the eastern and northeastern sections of the green belt (Podmoskov'e, Mytishchi, Balashikha, and Kuchino) definite quantities of sulfur dioxide, nitrogen oxides, chlorine and chlorides are present throughout the year.

In the western part of the city, that is, in the smoke-free sections of the city, these pollutants were absent or present in insignificant quantities.

Table 10 gives the maximum concentrations of sulfur dioxide and nitrogen oxides in the air of the eastern and western forest-park.

Table 10

Air Pollution in Moscow Forest-Parks in 1962
Maximal concentrations in mg./m.^{3}

Location	Sulfur dioxide	Nitrogen Oxides
	Smoke-polluted Regions	
Balashikha.	0.3	0.7
Podmoskov'e	1.1	1.87
Mytishchi	0.3	0.48
Kuchino	0.9	0.27
	Smoke-free Regions	
Khlyupino	Not found	0.7
Sharapovo	Not found	Not found
Nikolina Gora	Not found	0.12

The high concentrations of nitrogen oxides and the absence of sulfur dioxide in the air samples taken in Khlyupino Forest Preserve and Nikolina Gora is because the samples were taken at the edge of the forest, next to the highway carrying heavy traffic. The samples from Sharapovo, taken at a distance from a highway, did not contain any nitrogen oxide.

Still more revealing were the analytical results obtained in a study of the degree of rainwater pollution with greater industrial discharges and soluble nitrogenous substances in the eastern areas of Moscow compared to the rainwater of the non-polluted areas. The highest content of soluble and insoluble aerosols was found in rainwater near Moscow (Podmoskov'e forest park). Less of it was found in the Kuchino and Balashikha sections, followed by the Mytishchi forest-park and by Zvenigorod section which contained the least soluble aerosols.

Assuming the quantity of aerosols found in atmospheric precipitation of the Zvenigorod section to be 100, then in the Podmoskov'e forest-park it would be 1126 insoluble and 271, soluble; in the Balashikha and Kuchino district it would be 495 and 253, respectively; and in the Mytishchi, 239 and 180, respectively. The content of sulfates and chlorides in the atmospheric precipitation of smoke-polluted sections was 3 to 4 times that of smoke-free sections. Thus, the atmospheric precipitation falling on the soil acidifies the latter continuously which in turn affects the soil balance and the growth of trees, Table 11.

Table 11

Atmospheric Air Pollution in Smoky Regions of Moscow's "Green Zone"
(Averages in mg. per cubic meter per day beginning
December 1961 through October 1962)

Location	Insoluable Aerosols	Ash	Sulfates	Chlorides
Podmoskov'e	428	287	217	13
Kuchino	188	108	181	9
Mytishchi	91	56	135	5.5
Nikolina Gora	38	16	57	4.8

The laboratory data on the air and rainwater pollution with injurious substances in the eastern part of the forest-park belt are in complete agreement with the condition of the coniferous plantings found there.

Examination by foresters of the trees standing in the designated plots gave the following results. The condition of the tree was defined as "dry", "half-withered" (sick), and "healthy". The results are summarized in Table 12.

Table 12

Condition of Standing Timber in Areas in 1962
(In Percent)

Location	Condition of standing timber		
	Dry	Sick	Healthy
	Smoke-polluted Regions		
Balashikha	---	83	17
Podmoskov'e	---	100	--
Mytishchi	1.0	84	15
Kuchino	4.0	55	41
	Smoke-free Regions		
Khlyupino.	---	4.0	96
Stepanovo.	1.0	3.0	96
Sharapovo.	1.0	2.0	97
Nikolina Gora.	---	---	100

The same holds true for the growth increment of pine and spruce stands. Data for the period 1956-1961 are given in Table 13.

Table 13

Growth Increment of Pine and Spruce Stands in Centimeters Per Year

Location	1956	1957	1958	1959	1960	1961
Balashikha (Spruce - 80 years)	3.2	4.0	3.6	3.0	3.5	3.4
Mytishchi (Spruce - 73 years)	4.5	5.0	4.6	3.0	2.4	9.6
Sharapovo (Spruce - 73 years)	---	19.0	16.6	25.0	20.8	19.8
Stepanovo (Spruce - 73 years)	25.0	18.0	20.7	17.0	16.0	27.0

The A. P. Shcherbakov determination of sulfur and nitrogen contents in the conifer needles of pine and spruce, and microbiological study of the soil in the smoke-polluted and in the control sections of suburban Moscow show their direct relation to the air pollution.

Pine and spruce needles in smoke-polluted forest-parks contained appreciably more sulfur (% of dry weight) and less nitrogen (in mg./100 needles) than the needles in smoke-free sections. Correspondingly, the nitrogen and microorganism content of the soil was lower in the smoke-polluted areas than in the control areas. These conditions cannot be without effect on the nutrition and development of the trees. Table 14.

Table 14

Sulfur and Nitrogen Content in Pine and Spruce Needles and count of Micro-organisms in the soil (Averages)

Locations	% of S on dry weight basis	MG of N per 100 needles	Thousands of micro-organisms per 1 G of dry soil	Region
	Spruce - 80 years			
Kuchino	0.19	5.2	637	Smoke-polluted
Sharapovo	0.12	5.7	2002	Smoke-free
Mytishchi	0.20	5.5	----	Smoke-polluted
Stepanovo	0.14	7.1	----	Smoke-free
	Pine - 80 years			
Podmoskov'e	0.20	11	1209	Smoke-polluted
Khlyupino	0.1	22	1835	Smoke-free
Balashikha.	1.17	13.9	----	Smoke-polluted
Nikolina Gora . . .	0.12	29.5	----	Smoke-free

The air pollution of Moscow and its environs affects adversely not only the leaves of trees but also their annual increment. The polluted air causes premature aging of the plant organism as a whole, shortens its life cycle, and lowers the biological resistance of the trees to plant disease and insect pests. The timber reserve declines, and its quality is lowered by one to two grades. All this leads to a progressive destruction of pine and spruce stands, particularly in the eastern, northeastern, and southeastern sections of the Moscow green belt. In these areas the annual removal of dry and diseased trees exceeds the annual increment 3 to 4 times. The damaging effect of gases on conifers is at its worst in the autumn and winter seasons. During the heating season, air pollution by sulfur dioxide is more intense, and since sulfur dioxide is heavier than air, it does not rise high but spreads over the ground.

Weather conditions may aggrevate the adverse effect of industrial smoke and gases. Fog, dew, precipitation, and high relative humidity augment the deleterious effect of pollutants on plants. In winter, products of incomplete combustion combine with fog or dew droplets to form condensation nuclei in the damp air hovering close to the ground. Taken singly, the various components polluting the air (carbon monoxide, carbon dioxide, sulfur dioxide, tars, and others) are less injurious and less aggressive than their mixture. Fog concentrates all these substances, their effect is combined and their synergetic action is more damaging to vegetation. Wind direction and intensity may also affect the degree of damage of air pollutants on plants.

In examining the question of the effect of the injurious admixtures of smoke and gases on vegetation, one must take into account the protective role of green plantings blocking the penetration of polluted air downwind. The results of the investigations of V. F. Dokuchaeva and others have been instrumental in recommending the establishment of plantings to serve as shelter belts for the protection of forest stands of more valuable species against smoke and noxious gases and for prevention of physiological injury to plants by mechanical and chemical air pollutants. This effect appears twofold. Direct action of gases on the assimilation apparatus of the leaves results from the adsorption of sulfur dioxide through the stomata. This disturbs the assimilation of CO_2, lowers photosynthesis, inactivates the iron in the chloroplasts, quite frequently heightens respiration, the respiration coefficient exceeds 1, vitamin B is destroyed, the protein and carbohydrate balance is disturbed, and silicic acid and strontium accumulate in the leaves.

In the smoke-polluted sections of the Moscow forest-park belt, the coniferous tree needles and buds are very sensitive to air pollution. In both, in old and young trees, the absolute height of green and dry needles as well as the length of the needles are reduced sharply. Also, the average linear increment of apex shoots and the average weight of terminal and lateral buds decreases, all of which is, of course, related to the decline in the synthesizing activity of the foliage and to the disturbance of the growth processes. Quite the opposite occurs in the number of needles per unit length of shoot. The number of needles per cm. length of annual growth was appreciably higher on trees growing in smoke-polluted sections than on trees standing on smoke-free ground. The needles on apical and lateral shoots appear broomlike and grow closely bunched and appreciably shorter.

Air pollutants reduce the number of healthy trees 6 times, the number of dried-up and drying-up trees increased 85 times, as compared with the trees growing under conditions of pure air. The annual height increment for the last 5 years declined by 13 to 73%. Concurrently with weakening and drying-up of trees, there is the appearance of large numbers of various trunk-infesting insect pests, while on control plots of spruce stands only single trees had their trunks infested by insect pests (one to two trees per 0.5 ha.).

Indirect action of smoke and noxious gases in the air is exerted through the soil. Although the soil posseses a certain buffering action, yet systematic and prolonged acidification of the soil shifts the direction of chemical processes, its bases are depleted, soil gas-equilibrium and soil microbiological activity is disturbed, soluble aluminum and strontium salts accumulate, all of which upset the normal nutrition of plants. Ultimately, all the particles of smoke, soot, dust, and gases polluting the air return to the soil. Some of these, such as silicon, fluorine, lead, copper, zinc, chromium, strontium, and others, in minute quantities are essential plant nutrients, although in large quantities they are toxic. Heavy metals penetrate the soil down to 25 cm. The soil absorbs enormous quantities of these substances.

The negative effect of chemical and mechanical air pollutants is more pronounced in forest soils than in arable soils, notwithstanding the higher buffering effect and the higher raw humus content of the former. Tillable soils are plowed and fertilized annually, and this counteracts the deleterious effect of smoke-gases.

Different tree and shrub species exhibit differently their biological resistance to chemical and mechanical air pollutants. Among the conifers, the most resistant to air pollution is larch, which changes its needles annually. It is followed by pine, which changes its needles every 2-3 years, then by fir changing its needles every 3-5 years, and last by spruce, which changes its needles once in 7 years.

Some investigators classify woody species into 3 groups with regard to their resistance to smoke-gases, namely: highly resistant, slightly susceptible, and very susceptible. The criteria for this grouping are: premature dropping of leaves or needles, the appearance of spots on leaves, baring of crown tops, lowered resistance to insect pests, and the reduced annual increment both in height and diameter.

The symptoms were utilized by us in determining the extent of injury caused by smoke-gases to the growth of spruce and pine stands in the eastern sections of the Moscow forest-park belt.

Work is being done on diagnostic procedures to permit determination of the presence of noxious substances in the air from visible symptoms or by analyzing the leaves (presence of SO_2 and wax). In some cases bio-indicators can be used successfully: gladiolus, for the determination of fluorine; pine, a plant capable of accumulating sulfates without signs of injury; bluegrass, a plant sensitive to general air pollution by gases; sunflower and mazzard cherry, plants sensitive to the presence of sulfur oxides in the air.

In conclusion, it is necessary to point out possible measures for increasing the viability of tree stands in the eastern section of the Moscow forest-park belt.

The literature often points to the possibility of the use of mineral fertilizer for this purpose. Systematic application of mineral fertilizer -- and, primarily, calcareous and calcareous-magnesian (limestone, dolomite, marl and others), combined with nitrates -- to the soil in areas subjected to the action of acid gases and smoke, may greatly improve the soil structure. A recommended procedure is to apply in autumn lime, dolomite or marl 2 to 3 tons per hectare once in 3 to 5 years. This is an effective and economically feasible practice in forest-park management. It is also highly desirable to apply, every other year, in springtime, 100 kg./ha. of ammonium nitrate. This application is best done by broadcasting and subsequent raking or hoeing. One may also resort to spraying young trees with a 0.5% solution of urea - - a practice that will improve the growth of the young trees.

The study on the effect of smoke-polluted air on conifer stands leads to the conclusion that sulfur dioxide is destructive to coniferous trees. It is evident that the limit of tolerance of sulfur dioxide by conifers is lower than admissible by health standards. Apparently, it must be within the limits of 0.10-0.20 mg./m^3 .

In order to alleviate the effect on green plantings of air polluted with sulfur dioxide, it is recommended: (1) that the thermal power stations should be removed outside the city, with due regard to prevailing winds, and (2) that special agro-technical practices be adopted to counteract the injurious effect of acid gases on the soil.

In afforestation of suburban areas subjected to industrial exhausts and, particularly, to sulfur dioxide, it is advisable to establish complex plantings -- complex in form (multi-stage) and in composition (4-5 species) consisting of an assortment of smoke-resistant trees and shrubs. It is also imperative to set out forest shelter belts of gas-resistant species in order to provide protection to the green plantings in parks and forest-parks from the injurious effects of industry.

The Moscow Sanitary-Epidemiological Station deems it necessary to devise standards for the protection of green plantings; namely:

a) to fix a single permissible concentration of atmospheric pollutants safe for vegetation;

b) to establish a single classification of smoke-and gas-resistant trees, shrubs, and flowers recommended for planting, depending on the chemical pollutants in the air of inhabited localities;

c) to recommend procedures for combatting withering of conifers in city parks and forest-parks listing agro-technical practices for improving the structure and fertility of the soil, and for improving the vitality and productivity of arboreal plantings; and

d) to develop practices designed to attract birds into the forest-parks.

These measure may greatly assist the practical work of architects, foresters, forest managers, and those engaged in planning, planting, and the management of greenery. A similar suggestion was submitted by the Moscow Sanitary-Epidemiological Station to the central committee of the All Russian Society for the Protection of Nature and Green Plantings.

URGENT QUESTIONS CONCERNING VERDANT PLANTINGS IN THE CITY OF BAKU.

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Agricultural Council on Verdant Plantings in the City of Baku.

From Akad. Nauk SSSR. Ural. Filial. Komis. po Okhrane Prirody. Rastitel'nost' i promyshlennye zagryazneniya. Okhrana Prirody na Urale. V (Sverdlovsk, 1966). p. 177-179.

As a result of many years of skillful selection and utilization of drought-resistant woody and herbaceous ornamental plants, Baku has been transformed into one of the most verdant cities of the Union. Visiting guests admire the beauty of the city, its new buildings, and the many verdant areas. However, the surroundings of Baku are endowed with many natural advantages and these could benefit even more by additional plantings.

While the areas of verdant plantings are increased and the plant selection enriched, the struggle must be continued against air pollution of the city by various industrial wastes, such as noxious gases, smoke, dust, and the like. Regretably, in the very center of Baku, many buildings (city hall, university, Academy of sciences, Wedding Palace, and others) are still oil-heated and vent enormous volumes of smoke and soot into the air.

The newspapers have frequently reported air pollution by pyrite cinders from the Frunze sulfuric acid plant. Azerbaydzhan scientists have proved time and again the possible use of this waste for the production of trace elements as fertilizers which greatly improve the yield of wheat, cotton, and other crops. Nonetheless, hundreds of tons of this valuable raw material are carried daily to the dump. The fine caustic dust of pyrite cinders is blown into the air even by slight breezes, and in Baku there are always strong winds. Thus, a valuable raw material is lost for agriculture, and the air around settled communities is contaminated.

In the spring-summer period the leaves and shoots of woody and herbaceous plants turn gray and unsightly because of wind-carried dust and soot. Ash particles accumulate in leaf stomata, interfering with the normal transpiration of the plant, and the latter is then exposed to sunburns. The air under the trees is dusty and breathing is difficult. In these conditions, the usefulness of green plantings to man is greatly decreased. The flowers of shrubs and herbaceous plants must be washed off by sprinkling in the early morning hours or, preferably, in the evening. This removes the deleterious soot and dust from the plants, moistens the air and the soil, thereby providing favorable conditions for normal development of plants, while enriching the air with water vapor and oxygen. This is especially important to the gardens and parks of sanatoriums and rest homes where the sick and recuperating patients spend their time in the shade of trees. In the Apsheron sanatoriums, the green plantings are set in shallow soil (sand with underlaying limestone) and the lack of irrigation retards plant growth and renders them less useful. Thought should be given to additional water resources (wells, pumps) for irrigation of plants around sanatoriums and rest homes (Mardakyany, Bil'gya, and others).

Attention should be paid to verdant plantings on the ground of Baku hospitals and to the maintenance of plantings already in existance. Greenery near hospitals is of great health value. Flowers enliven the looks of the establishment and are beneficial to the morale and psychological well-being of the patients. Fruit trees, in addition to their decorative value, yield fresh fruit for the fare of the patients.

The grounds of the Shikhov balneological spa (near the village of Khandar) are in a very sorry state with respect to landscaping. Actually, there is no area suitable for plantings. However, behind the hospital building there is a large area of water that is linked to the sea and where small craft come for repair. Part of this area, adjacent to the sanatorium, could be drained and converted into a park for the patients. In large cities the norm of green plantings per person is calculated to be an area of 12-15 $m.^2$ or more. In Baku, in 1962, it was around 4.2 $m.^2$ which is totally inadequate for the local conditions of a dry and hot climate. Yet, there are architects who plan verdant areas in Baku and consider possible lowering even this ratio.

The results of many years of phenological observations and studies of biological and ecological characteristics of the major ornamental woody species in the difficult conditions of Baku led to the conclusion that scarcity of atmospheric precipitation and irrigation water, dryness of air and soil, insufficient plant nutrition in the soil, high heat, excess sunlight, and frequent strong winds weaken green plantings and cause premature leaf drop. If to this be added air saturated with noxious gases and dust, and a soil contaminated with industrial wastes, petroleum, and acids, it is clear that the area of verdant plantings in Baku should not be decreased but rather increased.

Some specialists recommend the use of waste water for irrigation of street plantings. True, waste water acts favorably during the first few years of plant growth and development of trees, particularly conifers, such as pine, cypress, oriental arborvitae, olive trees, Japanese privet, and others; waste waters were also beneficial to vegetable and melon fields. However, this has its negative aspects as well. The use of waste water for irrigation of green plantings near inhabited areas is undesirable for hygienic reasons: unpleasant odor and a chance of spreading contagious diseases. Also, continuous use of waste water for irrigation without dilution with fresh water over a period of many years contaminates the soil, and eventually affects plants adversely. The area of Akhmedlinsk plateau (the nursery of the Park Department of the Baku city executive committee "Zelentrest Bakgorispolkom") may serve as an example.

The sewage from Shaumyan treatment station is essentially the waste from petroleum, sulfuric acid, and other plants. According to data of the sanitation and hygiene station, this water contains large quantities of alkalies, ammonia, and chlorides, all injurious to plants. In summertime, the chloride content of the sewage is 1288 mg./l. Thus, each irrigation brings into the soil around one ton of chlorides per hectare. This is very injurious to plants, and gradually causes salinization of the soil. The chlorides are especially injurious to laurel cherry, pittosporum, roses, evergreen buckthorn, and others.

A few words concerning the application of fertilizers to verdant plantings may be desirable. Gardens, parks, squares, and other massive and street plantings in Baku are almost never fertilized, whereas organic fertilizer in any desirable quantity can be prepared from city refuse. It staggers the imagination what a wealth of organic matter is carried daily outside the city and burned. It is true that ashes could also be used as fertilizer; however, in order to obtain a complete organic fertilizer, burning should be avoided because useful organic substances are lost in this process.

The maintenance of city verdant plantings is also inadequate. The biological and ecological characteristics of the plants that require different care are not taken into account. Pines and cypresses evaporate little moisture compared with broadleaf trees and shrubs, such as oriental plane tree, poplar, ash, and others, and yet, they are irrigated alike.

Trees planted on streets are subject to more adverse environmental conditions than trees growing in gardens and parks, and therefore should be cared for differently. Yet, trees on streets are neither shaped nor pruned, and thus age quickly and their tops wither (e.g. black locust, corkbark elm, and others).

There exists in Baku for many years an agricultural council dealing with problems of verdant plantings in urban areas. Among its members are highly qualified landscape specialists representing various scientific and industrial institutions. Regretably, many of the serious problems relative to verdant plantings in the city, which are rightly the function of this council, are never presented for its consideration but are carried out by administrative procedure. Therefore, sometimes the work relating to verdant plantings is carried out poorly. Further development of the program of making cities verdant in Azerbaydzhan requires basic improvements in method of management and the broadening of the relevant scientific research work.

AN EXPERIMENT IN CREATING PROTECTIVE PLANTINGS IN THE CITY OF KRASNOURAL'SK

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From Akad. Nauk SSSR Ural. Filial. Ural. Gos. Univ. Im. A. M. Gor'kogo. Okhrana prirody na Urale (Sverdlovsk) 4:189-195, 1964.

Krasnoural'sk is a big center of copper smelting and chemical industry in the Central Urals. The copper-smelting combine built in 1930 discharges into the atmosphere appreciable volumes of sulfur dioxide and fluorine, both of which are injurious to vegetation and man. During the existence of the smelter, sulfur dioxide destroyed the natural forest situated nearby in the northeastern part of the city. As a result of this loss of vegetation, the city became unattractive, dingy and dusty. The concentration of noxious gases in the air exceeded the permissible limits 8-10 times. The average number of gas-polluted days during the growing season and during the year was 15 and 23 respectively. There were no green plantings in the city. Attempts to make the city verdant through the use of plant material introduced from the outside failed.

At that time, there was very little investigative work or practical experience dealing with the establishment of green plantings under such conditions. The limited scientific data developed elsewhere concerning practices in other cities were of little use under local conditions, and the usually recommended assortment of gas-resistant plants were found to be unsuitable for this area.

The local unsanitary working and living conditions created a big turnover of the labor force. Such was the situation in 1947 when our work, which aimed to make this city green, was started.

The selection of trees and shrubs adapted to local environmental conditions was our first problem. To this end, an arboreal nursery was established in 1939. However, because of World War II, the work of the nursery could not continue and did not actually begin till 1947. . . .*

Most of the seedlings in the nursery survived the war. This material was utilized for planting some areas of Krasnoural'sk. In 1948 experiments were started in various parts of the city with the aim of selecting a resistant assortment of trees and shrubs. By 1955, after 6 years, we have arrived at certain conclusions; the most important one being that only locally grown gas resistant plant material should be used in city plantings.

We have established that the degree of gas resistance of a given arboreal species is not a constant one: that gas resistance is likely to change, depending on the locality where it was grown, the degree of exposure to gas pollution, and the effect of gas pollution on the seedling during the period of its growth and development. The nearer the nursery was to the smelter and the more the seedlings were exposed to gas, the greater was the gas resistance of the seedlings grown in the nursery. Gas resistance tests were carried out in plots located 20 to 500 meters from the smelter.

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* Editor's note: Ellipsis points indicate the omission of material not relevant to the subject of air pollution.

A brief summary of the observations is given in Table 1. In the experiments, 7 species of trees and 11 species of shrubs were used.

Table 1

Species	Number of trees	Number of trees perished		Condition of trees
		trees	%	
Apple tree	30	-	-	Normal increment and fruiting
Aspen	30	2	7	Increment below control by 12-15%
Norway maple	30	3	10	Increment below control by 12-15%
Manchurian ash	30	5	17	Increment below control by 15-18%
Balsam poplar	30	8	27	Increment below control by 18-22%
Little leaf linden	30	24	80	Increment below control by 70%
Birch	30	29	97	Increment below control by 95%

The most gas-resistant species was found to be the apple tree, while birch and linden were excluded from the assortment of plant species suitable for planting under local environmental conditions.

Of the shrubs, the most resistant were: redhaw hawthorn, hedge cotoneaster, common laurel cherry, common chokecherry, black currant, hairy lilac, and Tartar honeysuckle. Most of the plants utilized for this experimental planting were taken from nurseries in other areas of the Sverdlovsk district.

The value of the local planting material became clear to us somewhat later, after 1950, when we started extensive plantings along streets and in plazas, and began laying out small gardens, municipal parks, and the like.

In 1953 we planted in a newly established city park plants of Siberian pea shrub, some of which came from our own local nursery and some, from a nursery in Nizhniy-Tagil. The planting was done late in fall. In the spring of 1954, after leaves developed on the plants, the first wave of sulfur dioxide struck the plants. The leaves on the pea shrub from Nizhniy-Tagil were severely injured, while the leaves on plants from the local nursery remained normal in appearance.

As was already pointed out, birch transplanted from the forest, where the exposure to gas was small, perished almost entirely. In contrast, northeast of the smelter, within a large wasteland, formed by discharges of industrial acid waste and subject to constant gas pollution, on soils where even grass did not grow, we found an area of about 90 hectares with thickets of 8 to 10-year-old, well-developed birches, about 2 meters high and having thick green crowns. It is our opinion that these birch trees grew from seed brought there from distant, healthy, non-polluted forests; that, notwithstanding the unfavorable conditions, the seed germinated; and that the seedlings grew and developed into trees because as young plants they were able to adjust themselves easily to the new surroundings. True, these plants have a very shallow root system located in the first 5 cm. of the soil. Nonetheless, transplanted into the city, the birch takes root and grows well.

We have developed an assortment of gas-resistant species for city plantings. The trees of this assortment are: poplar, birch, cedar, larch, aspen, maple, ash, elm, bird cherry, mountain ash, ornamental apple trees, pear trees, and cherry trees. The shrubs of this assortment include: Siberian pea shrub, barberry, elder, dogwood, woodbine, Juneberry, viburnum, hedge cotoneaster, hedgerow rose, hairy lilac, Alpine currant, sweetbrier, redhaw hawthorn, and so on. In this area, frost resistance of the plants is of very great importance and this is especially true in reference to fruit-bearing plants. Spring frost coupled with sharp diurnal changes of temperature and particularly, late May and July frosts, affect adversely the plants during their period of blooming. Early autumn frosts also have an adverse effect.

Following are the data of the metereological station of the Krasnoural'sk Municipal Park Service of the first and last frost for the last 10 years.

Frost Data

Year	Late Spring		Early Autumn		Frost-free period
	Date	Temperature in °C	Date	Temperature in °C	
1947	18/V	-1.5	7/IX	-2.0	111 days
1948	29/V	-1.5	10/IX	-0.7	103 days
1949	1/VI	-0.8	2/IX	-0.5	92 days
1950	4/VI	-5.6	3/X	-0.6	126 days
1951	25/VI	-1.6	23/VIII	-1.5	58 days
1952	15/V	-0.0	18/IX	-1.1	125 days
1953	24/V	-0.0	26/VIII	-0.0	95 days
1954	30/V	-2.0	11/IX	-1.5	103 days
1955	16/VI	-2.5	11/VIII	-1.0	55 days
1956	3/VII	-0.0	5/IX	-1.0	57 days

For this area the average summation of temperatures above 0°C. during the growing season is 2134°; the total precipitation, 339 mm.; the yearly mean temperature is 0.4°; and the duration of the growing season is 140 days.

The local average number of frost-free days for a period of 10 years was 92, late spring and early autumn frosts are very frequent, at which time the temperature may fluctuate 15° C. or more, (Table 2).

Table 2

Number of Daily Spring Meltings and Freezings - - Ten-year observations

Year	March			April			May			June			July		
	No. of fluctuations	Maximum	Minimum	No. of fluctuations	Maximum	Minimum	No. of fluctuations	Maximum	Minimum	No. of fluctuations	Maximum	Minimum	No. of fluctuations	Maximum	Minimum
1947	14	7,0	5,0	15	5,0	10	5	5	4,5	—	—	—	—	—	—
1948	5	3,5	13,5	21	11	4	6	20,5	3	—	—	—	—	—	—
1949	4	4	19,5	20	10,3	6,4	8	7,0	2	1	11	0,8	—	—	—
1950	3	3	8,3	13	9,8	8,1	13	7,5	5,5	2	20	1,5	—	—	—
1951	16	17,2	16,1	11	19,5	2,8	13	14,5	5,5	1	12,3	1,6			
1952	4	6,2	11,1	18	10,2	15	11	10,5	13,2	—	—	—	—	—	—
1953	4	4,3	8,5	18	19,5	5	7	16	9	—	—	—	—	—	—
1954	9	5	10,1	22	4	6,4	10	13,8	5	—	—	—	—	—	—
1955	10	4	14	13	8,5	3,5	7	4,3	10	3	30	2,5	3	19,5	1
1956	14	5,5	17	21	12	6	18	15	6	5	24	1	1	21	0

Note: Temperature fluctuations given in °C.

Such temperature fluctuation within a day cannot remain harmless to plants; it causes cell rupture of young bark and cambium. Bark burns are inevitable under such conditions. The danger lies in the fact that during the blossoming period such temperature fluctuations lead to the loss of the fruit buds.

Sharp, daily, temperature fluctuations and the low-minimum winter temperatures (down to -46° C.) compel the search for new agro-technical methods to develop a greater frost resistance in plants. We decided to change the agrotechnical procedures of raising plants and of their care, namely: by raising the plants in the nursery under cold, spartan conditions, without irrigation and application of fertilizers in order to render the plants hardy. The effectiveness of this method of raising planting material is attested to by the successful development of horticulture in our city. At the present, fruit-bearing plants in our orchards do not suffer even when temperatures of -6° C. occur during flowering. The new procedures of growing nursery stock have enabled us to utilize a wide variety of plants for city plantings. Now, along with standard planting material we are also setting out larger stock, and even plant, during summer, trees in full foliage. This enables us to accelerate the establishment of green plantings in the city. The central downtown streets of the city became completely green, with large shade trees and abundant shrubs and flowers. The first lawns appeared in the city. Eleven squares, a boulevard, and a park were laid out in the city. At the present, for each resident of the city there are 15 $m.^2$ of green plantings for general use. This does not include the street trees and the three collective and over 2000 private gardens of the city.

The city is completely transformed. One absent for 5 to 7 years will not recognize the streets nor the plazas. The microclimate changed too; it became milder; the air, cleaner; and the eyes feast on flowers and abundant greenery. Even in winter the city looks dressed up. Our streets, boulevards, and squares are teeming with leisurely walking and resting people, and are full of children. True, sulfur dioxide still exerts its deleterious effect during easterly winds but the greenery reduces sharply the effect. Labor turnover in the city also decreased sharply.

The immediate task of the park service is to make Krasnoural'sk a garden city, the most beautiful inhabited place in the Sverdlovsk district. The foundation is ready -- a 55 hectare nursery, a stock garden, a plant-breeding area, and a metereological station. The planting material is gas- and frost-resistant, and have a well developed root system. Now we are setting out only large-size trees and shrubs. There is a large demand for the planting material of our municipal park service from other sections of our district -- the demand testifies to the high quality of our planting stock. We are raising seedlings for the city and breeding new fruit varieties. It is generally recognized by experts that Krasnoural'sk is the cradle of the Ural plum.

Within the next two years will be completed the establishment of green plantings on the city's last few wasteland areas and in the new housing developments. Much attention is now devoted to the establishment of lawns and flower beds on streets, squares, and plazas. The local soil is heavily poisoned by noxious gases from the smelter; we are thus compelled to create new soil and fills enriched with humus and duff brought from areas beyond gas contamination. The new fills are 20 cm. thick and the sheer volume of it slows down the planting work because each hectare of lawn requires 2000 $m.^3$ of soil.

CONCLUSIONS

The city of Krasnoural'sk, which is subject to rather specific severe local conditions for the establishment of green plants, has been transformed into a green, wholesome, beautiful city with parks, squares, boulevards, and green streets. We, who specialize in making cities verdant, are convinced by our own experience that a city can be turned into a garden-city even under such difficult conditions as our city presents. This confirms the fact that the planting materials for gas-polluted areas should be exclusively local, raised in the same noxious medium where they are to continue their growth, and raised under rigorous, spartan conditions.

To make the city of Krasnoural'sk verdant took more than 20 years counting the time from the foundation of the nursery. The long period of time, which was required to achieve the desired objective, is to some extent justified by the enhanced stability, i.e., resistance to air pollution of the green plantings of the city. To further the greening of Krasnoural'sk, it is very important that the copper-smelting combine install new effective gas and dust purifiers in order to reduce air pollution. This will enable us to enlarge greatly the assortment of plants suitable for use in the city.

TREES AND SHRUBS FOR MAKING THE DONETS COAL BASIN VERDANT

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From Akad. Nauk SSSR Byulleten' Glavnogo Botan. Sada. vip. 45, (Moskva, 1962) p. 34-37.

The establishment of verdant plantings for general use in the Donets Coal Basin was begun only after the Great October Socialist Revolution. These plantings assumed an ever increasing importance by the end of the first Five-Year Plan. At the beginning of the second Five-Year Plan (1933) the total planted area of the Donets Coal Basin comprised 1,773 hectares, but at the end of this five-year period, the planted area was already 4,143 hectares. During the same period in a number of cities the area under plantings increased about 3 to 4 times. The green plantings began to spread at a particularly rapid rate after the conclusion of World War II. Thus, specificially, in Donetsk in 1960, there were 9,514 hectares under verdant plantings for general use, not counting 30 hectares under lawns and 13 hectares under flower gardens, which amounts to 9.58 M^2 of green plantings per person of the city population; at the end of 1965, it has been planned, to have the planted area increase to 14 M^2 per person. During the recent five years, in the Donets oblast' alone (according to data of the Regional Department of Communal Economy for 1960) 42,980 hectares of green plantings were established. In the subsequent years, the effort to establish verdant plantings will, according to plans, increase considerably.

In 1960 the major green plantings of the cities and the workers settlements in the Donets oblast' were investigated. The area studied included the city of Donetsk and Gorlovka (Figures 1 and 2)*, Nikitovka, Artemovsk, Konstantinovka and others. The plantings in these localities were studied in order to ascertain the most promising species of trees and shrubs that have proved to be hardy under local environmental conditions. The methods of investigation consisted of plant inspection with checks on the plants' origin, their reaction to the conditions of growth, the interrelations between various plant species in the plantings, as well as in reference to the agro-technical care received. The ornamental aspects or decorative characteristics of plant were judged according to their general condition in relation to growing conditions and in relation to their utilization in various garden and park compositions. In characteristic environmental conditions (good care, no care, etc.) single measurements were taken of yearly growth, when necessary. The experience attained in park establishment was studied in relation to natural conditions and in relation to the objectives and purpose of the planting and the specific use of tree and shrub species in a given planting, as well as in relation to the time of the establishment of planting, and the outstanding characteristics of its composition.

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* These show photographs of gardens which could not be reproduced in this paper.

All together, in this 1960 study, there were recorded throughout the verdant plantings of the cities and workers' villages of the oblast' (excluding the forest-type plantings of the Veliko-Apadola and Zhanovskoy experimental forest stations) seven species of conifers, 64 species of deciduous tress, 44 species of shrubs, and four species of liana while in 1940, the green plantings of the same region contained only 28 species and forms of trees, 21 species of shrubs, and two species of liana (according to A. G. Barbarich, 1940, "Ornamental Plants of the Donbas," Botanical Journal, AN URSR 3-4).

The composition of plants in the populated areas of the region studied consists chiefly of introduced species. Twenty-four species are related to plants from the Euro-Siberian oblast'. Of these species, three species are self-sown: black poplar, Populus nigra; Norway maple, Acer platanoides; and Siberian pea-tree, Caragana arborescens. Four species suffer from drought: little-leaf and big-leaf linden, Tilia cordata and Tilia platyphyllos; European bird cherry, Prunus padus; and European mountain ash, Sorbus aucuparia.

Twenty-four of the introduced species are of North American origin and of these the following are self-sown: black locust, Robinia pseudoacacia; box elder, Acer negundo; Canadian poplar, Populus balsamifera; green ash, Fraxinus lanceolata. Two species, lilac-leaved catalpa, Catalpa sp.; and common mahonia, Berberis sp.; suffer from frost; and eight species suffer from drought: eastern red cedar, Juniperus virginiana; American arborvitae, Thuya occidentalis; catalpa sugar maple, Acer saccharum; European bird cherry, Padus sp.; white snowberry, Symphoricarpus sp.; Kentucky coffee tree, Gymnocladus canadensis; butternut, Juglans cinerea; and lilac-leaved catalpa, Catalpa sp.

From the Crimea , the Caucasus, Asia Minor, and Southern Europe come 22 species, of which eight are self-sown: Scotch elm, Ulmus scabra; smooth-leaved elm, Ulmus folicea; common or field maple, Acer campestre; Tartar maple, A. Tataricum; European ash, Fraxinus excelsior; spindle tree, Euonymus europaea; monoseed hawthorn, Crataegus monogyna; and dog rose, Rosa canina. One species suffer from frost, English walnut, Juglans regia; and two suffer from drought, silver linden, Tilia tormentosa and common mock orange, Philadelphus sp.

The plants of China and Japan are represented by 11 species, one of which is self-sown, barbarian wolfberry, Lycium sp. Six species suffer from frost: oriental arborvitae, Thuya orientalis; tree of heaven, Ailanthus altissima; Japanese pagoda tree or Chinese scholar tree, Sophora japonica; white mulberry, Morus alba; fuzzy deutzia, Deutzia scabra; and Japanese quince, Chaenomeles japonica. Two species suffer from drought: oriental arborvitae Biota orientalis; and polychromatic weigela, Diervilla sp.

Afghanistan, Iran, and Central Asia are represented by six species, one of them is a self-sown species, Turkestan elm, Ulmus sp. One species, Lombardy poplar, Populus pyramidalis, suffers from drought.

Of five Mediterranean species, two suffer from frost: golden-rain laburnum, Cytisus laburnum and Spanish broom, Spartium junceum.

The plants of the Balkan peninsula are represented by two species: common lilac, *Syringa vulgaris* and horse chestnut, *Aesculus*, spp. which suffer noticeably from drought.

Two Far Eastern species, Amur cork tree, *Phellodendron amurense* and Manchurian walnut, *Juglans mandschurica*, suffer noticeably from unsuitable environmental conditions.

Of the plants from the southern European parts of the USSR, a widely spread species is the pentandrous tamarisk, *Tamarix* sp. which suffers from drought and gases.

From the 20 hybrid and garden types of plant species recorded in the oblast', the most promising plants are: globular black locust, *Robinia pseudoacacia*; variegated golden box elder, *Acer negundo*; silver maple, *Acer sacharinum*; golden maple, and purple sycamore maple, *Acer pseudoplatanus*; Pissardo plum; weeping European ash, *Fraxinus excelsior*; Van Gutta spiraea; a strain of rose; and others.

In the forest plantings of Veliko-Anadola and in the plots of the arboretum and the plantings of the Zhdanovskoi experimental forest station are grown: 18 coniferous species and forms, 105 broad-leaved decidious trees, 74 strains of shrubs and two species of liana. The following suffer from frost: oriental arborvitae, *Biota orientalis*; tree of heaven, *Ailanthus altissima*; fig tree, *Ficus carica*; Japanese pagoda tree, *Sophora japonica*; wild pistache, *Pistacia mutica*; Judas tree, *Cercis siliquastrum*; red, lilac-leaved, and Japanese catalpa, paniculate"kel'reytereya"; English walnut, *Juglans regia*; Japanese quince, *Cydonid japonica*; common boxwood, *Buscus sempervirens*; pinnate bladdernut, *Staphylea* sp; holly-leaved mahonia, *Berberis* sp.; weeping forsythia; golden-rain laburnum, *Cystisus laburnum*; osage orange, *Maclure pomifera*; and Babylonian willow. The following suffer from drought: Colorado or white fir, *Abies concolor*; oriental beech, *Fagus orientalis*; laurel oak, *Quercus laurifolia*; zelkva, *Zelkova carpinifolia*; Caucasus wing nut, *Pterocarya* sp.; horse chestnut, *Aesculus* spp.; yellow buckeye, *Aesculus octandra*, hickory pecan, *Carya pecan*; Chinese catalpa, *Catalpa ovata*; American white wood, *Liriodendron tulipifera*; butternut, *Juglans cinera*; Manchurian walnut, *Juglans mandschurica*; eastern Canadian spruce, *Picea canadensis*; Norway spruce, *Picea excelsa*; and blue spruce, *Picea pungens*. Self-sown plants are: black locust, *Robinia pseudoacacia*; Siberian pea tree, *Caragana arborescens*; common and Turkestan elm; smooth-leaved elm, *Ulmus foliacea*; Armenian elm, *Ulmus elliptica*; summer oak, *Quercus* sp.; black poplar, *Populus nigra*; European ash, *Fraxinus excelsior*; green ash, *Fraxinus lanceolate*; Norway maple, *Acer platanoides*; field or common maple, *Acer campestre*; Tartar maple, *Acer tataricum*; box elder, *Acer negundo*; warty-barked spindle tree, *Euonymus verrucosa*; spindle tree, *Euonymus europaea*; monoseeded hawthorn, *Catregus monogyna*; common buckthorn, *Rhamnus cathartica*; and cinnamon rose, *Rosa cinnamomea*.

The geographical origins of these plants are as follows: North America--48 species and varieties; the Crimea, the Caucasus, Asia Minor and Southern Europe--46 species; Euro-Siberian oblast'--36 species; China and Japan--17 species; the Mediterranean--14 species; Central Asia, Iran, and Afganistan--12 species; the Balkans--9 species; the Far East--7 species; the southeastern European parts of the USSR--1 species; and, in addition, 9 hybrids and garden varieties.

Of these plants, 21 species are self-sown, 17 species suffer from drought and 21 species from frost.

Investigation has shown that the assortment of trees and shrubs which it is possible to recommend for street planting in the towns and settled parts of the Donets basin for the arrangement of gardens and parks, for making verdant farmstead areas, as well as for planting alongside roads and planting live hedges, differs little from the assortment, utilized for similar purposes in other steppe districts of the left-bank of the Ukrainian SSR.

However, this does not apply to industrial territories. In areas producing great amounts of smoke and gas, the assortment is limited to the following species: common quince, *Cydonia oblonga*; black locust, *Robinia pseudoacacia*; common privet, *Ligustrum vulgare*; crenulate and fuzzy deutzia, *Dutzia scabra*; garden woodbine, *Lonicera caprifolium*; oleaster, *Elaeagnus angustifolia*; common hoptree, *Ptelea trifoliata*; Japanese pagoda tree, *Sophora japonica*; eastern poplar, *Populus deltoides*; white mulberry, *Morus alba*.

In areas of average and low smoke pollution it is possible to add to the above list the following species: common apricot, *Armeniaca vulgaris* or *Prunus armenica*; indigo bush, *Amorpha fruticosa*; spindle tree, *Euonymus europaea*; Turkestan elm; monoseed hawthorn, *Crataegus monogyna*; English hawthorn, *Crataegus oxyacantha*; silver hawthorn, *Crataegus orientalis*; Altai hawthorn, *Crataegus altaica*; smooth-leaved elm, *Ulmus foliacea*; Mahaleb cherry, *Prunus mahaleb*; common honey-locust, *Gleditschia* sp.; common pear, *Pirus communis*; white willow, *Salix alba*; crack willow, *Salix fragilis*; common and Caucasian hackberry, *Celtis occidentalis* or *Celtis caucasian*; box elder, *Acer negundo*; holly-leaved mahonia, *Barberis* sp.; ground cedar or common juniper, *Juniperus communis*; goldenrain broom, *Cytisus* sp.; common box tree; bloody dogwood, *Cornus sangvinea*; common lilac, *Syringa vulgaris*; Persian lilac, *Syringa persica*; sumac, *Cotinus* sp.; common plum tree; golden current, *Ribes aureum*; Van Gutta spiraea, *Spiraea* sp.; Chinese poplar, *Populus simonii*; pendulous forsythia; cinnamon rose, *Rosa cinnamomea*; common crab-apple; and green ash, *Fraxinus lanceolata*.

For the planting of refuse dumps and waste piles, the following species are recommended: black locust, *Robinia pseudoacacia*; Siberian acacia, *Caragana arborescens*; common apricot, *Armenica vulgaris*; tree of heaven, *Ailanthus altissima*; indigo bush, *Amorpha fruiticosa*; Turkestan elm; silver hawthorn, *Crataegus orientalis*; monoseed hawthorn; Mahaleb cherry, *Prunus mahaleb*; smooth-leaved elm, *Ulmus foliacea*; Tartar honeysuckle, *Lonicera tatarica*; box elder, *Acer negundo*; common buckthorn, *Rhamnus cathartica*; oleaster, *Elaeagnus angustifolia*; common hoptree, *Petlea trifoliata*; oriental bladder senna, *Colutea orientalis*; sumac, *Cotinus* sp.; golden currant, *Ribes aureum*; black cherry, *Prunus serotina*; white mulberry, *Morus alba*; cinnamon rose, *Rosa cinnamomea*; and green ash, *Fraxinus lanceolata*.

For planting on slopes and wasteland it is possible to make use of the following species: black locust, *Robinia pseudoacacia*; indigo bush, *Amorpha fruiticosa*; spindle tree, *Euonymus europaea*; Turkestan elm; dwarf almond, *Amygdalus nana*; monoseed hawthorn, *Cartaegus monogyna*; silver hawthorn, *Cartaegus orientalis*;

Bessey cherry, *Prunus bessey*; Mahaleb cherry, *Prunus mahaleb*; smooth-leaved elm, *Ulmus foliacea*; silver "galemodendron"; box elder, *Acer negundo*; common buckthorn, *Rhmnus cathartica*; oleaster, *Elaeagnus angustifolia*; sea buckthorn, *Hippophae* sp.; oriental bladder senna, *Colutea orientalis*; bloody dogwood, *Cornus sangvinea*; sumac, *Cotinus* sp.; golden currant, *Ribes aureum*; eastern poplar, *Populus deltoides*; green ash, *Fraxinus lanceolata*; and European ash, *Fraxinus excelsior*.

For forest belts and green tracts around cities and workers' villages, the principal species is the common oak, *Quercus robur*. The after-growth species of this oak are: common apricot, *Armenica vulgaris*; Siberian pea tree, *Caragana arborescens*; warty-barked spindle tree, *Euonymus verrucosa*; spindle tree, *Euonymus europaea*; Mahaleb cherry, *Prunus mahaleb*; common pear, *Pyrus communis*; forest pear; *Pyrus* sp.; Tartar honeysuckle, *Lonicera tatarica*; oleaster, *Elaeagnus angustifolia*; bloody dogwood, *Cornus sangvinea*; sumac, *Cotinus* sp.; eastern poplar, *Populus deltoides*; green ash, *Fraxinus lanceolata*; and European ash, *Fraxinus excelsior*.

COMBINING PROTECTIVE AND ORNAMENTAL CHARACTERISTICS OF WOODY PLANTS

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In the planning of verdant plantings it is very desirable to combine the ornamental properties of plants with their utility for man's health. In this respect two groups of ornamental plants suggest themselves.

1. Fruit and berry trees and shrubs planted along streets and in parks.

2. Non-fruit bearing plants that contribute greatly to the improvement of the surroundings.

The first group comprises ornamental apple and pear trees, bigfruit hawthorn and sweet mountain ash, chokeberry, sweetbrier, sea buckthorn, sweet viburnum, and other plants.

The second group includes trees and bushes that absorb from the air noxious gases, carcinogenic substances, and radioactive dust. They strongly ionize the air and emit a large quantity of salubrious substances, favorably affecting lung tissue, blood vessels, and the nervous system of man. In the first group are known species that combine ornamental characteristics and useful fruit; our knowledge of the second group is rather scant. Frost resistance, gas resistance, growth characteristics, and methods of propagation have been studied in wild plants but of their contribution to man's health, very little is known. To attain a greater understanding of this matter would require complex biochemical and pharmacological investigations.

We shall briefly examine the potential usefulness of woody plants, comparing their ornamental qualities and their specific effect on man's health.

The combination of ornamental properties and utility of fruit and berry plants was hardly utilized at all. Horticultural plant breeders are primarily interested in the quality of fruit. The crown of the tree interests them only in relation to the ability to bear large crops but not for its ornamental properties. Landscape architects do not use fruit trees in parks and on avenues because the trees are not sufficiently ornamental and because of the danger to the trees from wanton fruit picking. Consequently, when fruit-bearing plants are used on city streets, the plants are usually either small fruit of the mulberry type in the southern parts of the country or the Siberean dwarf apples in the north, or else, consist of the winter varieties of pears, of little ornamental value, which are planted in Azerbaydzhan.

The absence of special selection has resulted in a dearth of fruit tree forms that would combine high decorativeness and the value of fruit which are rich in bio-active substances vital to the health of man. Apple trees, having a beautiful shape and bright red flowers, usually have no pendent crowns, and their frost-resistant varieties bear small fruit of indifferent taste. Hawthorn, bearing large fruit (of the type Rezan' Michurina) bears fruit insufficiently sweet and has dull flowers, although small-fruit hawthorns that have bright, fragrant, double flowers are known.

Apple trees with particularly ornamental fruit (Altayskiy golubok, Pepinka altayskaya, and others) have an insufficiently strong crown and easily breakable branches, while varieties having pendent crowns (Zolotinka, Tungus) have unattractive looking fruit.

There are, however, apple trees as well as other fruit and berry plants that have excellent ornamental characteristics. Through plant breeding and selection, these ornamental characteristics could be combined with the bearing of fruits of desirable size and taste.

Let us examine ornamental qualities of fruit-bearing species using the apple tree as an example. Ornamental apple trees comprise at least twelve groups, which upon hybridization are likely to produce plants with a most interesting combination of qualities.

1. Dwarf bushlike crabapple varieties having a thick crown: pear-apple, Toringo, Karlikovaya Dibrova, Kolyuchaya ULTI, Krasnolistnaya Budagovskogo.

2. Pyramidal and strongly growing arborescent apple varieties: Ural'skiy krasnyy ranet, Sibirka No. 1, Moshchnaya, Gigantskaya, Alleynoe, Gigant Chernenko, and others.

3. Pendent and semi-pendent crabapple varieties: low-growing seedlings of pearleaf pendent crabapple, Dibrov's pendent redleaf, Tungus, Zolotinka, Shatrovka, Elise Rathke seedlings and pendent trunk types, and others.

4. Colored-leaf apple varieties: seedlings of Niedzwetsky with red top, varigated and golden leaves. Close to these are numerous varieties of apples of which the leaves turn bright orange and red in autumn.

5. Apple varieties bearing ornamental blood-red or golden bright fruit, and in some cases having also lacey crowns: Altayskiy golubok, Gorno-altay-skoe, Pepinka altayskaya, Severyanka, Dolgo, and some others.

6. Winter-bearing apple varieties whose fruit remains on the branches during the winter and which do not lose their ornamental aspects after leaf fall: Vishneyablonya Bedro and Zimuyushchaya Dibrova.

7. Long blooming (10-12 days) and remontant crabapple varieties: "Pozdnotsvetushchaya", "Dvazdytsvetushchaya", and others.

8. Red-flowering crabapple varieties: seedlings of the varieties Komsomolets and Michurin's Krasnoznamennoe, which were obtained in various horticultural stations.

9. Double-flowered crabapple varieties described in the literature. In the Urals these are represented by the half-double Siberian crabapple.

10. Naturally low-spreading crabapple varieties: Stlantsevaya Isaeva and seedlings of Kur'yanova.

11. Crabapple trees whose fruit develops vegetatively through enlargement of tips of shoots and buds. Vegetatively propagated apple varieties: Chulanovka, Verbnoe, and crabapple trees having drooping shoots which attach themselves to the soil.

12. Bitter-fruit crabapple varieties: Meretikov gray-pink, Bedro Seyanets No. 14, Krutovskiy Chinese crab, Gor'kaya Krylova, and others.

The wild parents of the apple (common apple and Siberian crabapple), to which explanatory inscriptions may be attached can be planted in parks. Equally advisable is to plant apples of historic interest (from the Darwin orchard, from the Ul'yanov orachard, etc.)

A survey of the ornamental types of apples shows the enormous possibilities for improving this culture. No one can fail to be impressed at the sight of a long-flowering pendulous apple tree having bright red double flowers, particularly if the fruit is also tasty as well as decorative, as is the case with the variety Altayskiy golubok....*

In producing ornamental apple trees special purposes can also be kept in mind. For the purpose of verdant city plantings, it would be desirable to use low-growing varieties having pliable, unbreakable branches and bearing large fruit dropping off at maturity; this would prevent breakage of trees while picking the fruit. Particularly valuable are apple varieties and other ornamental species that can be propagated by cuttings. Some other species have also ornamental qualities which could be combined with the usefulness of their fruit.

Among the pears are ornamental pyramidal (Kiparisovaya) varieties and others bearing ornamental fruit. These are large, frost-resistant trees suitable for street and park planting.

Mountain ash comprise varieties having leaves ranging from silvery to golden colors, pendent or cupola-shaped crowns, and range from bushes to large trees. Their fruit ranges from lemon-yellow and bright red to cherry-colored and black (hybrids with chokeberry). Among the mountain ash are many varieties bearing sweet fruit (Nevezhinskie, and the hybrids of Michurin, Petrova, and

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* Editor's note: Ellipsis points indicate the omission of material dealing primarily with medicinal properties of plants and consequently, not relevant to the specific subject of air pollution.

Tikhonova). They are readily propagated by grafting onto the common bitter mountain ash. The fruit of the sweet mountain ash abound in provitamin A (carotene), P-active catechols, vitamins B_9 and K, and the Nevezhinskie variety contains also vitamin C. The chokeberry too is very ornamental, both in spring, during blooming and in autumn because of the red leaves and bunches of black fruit....* Of special interest are varieties having a small number of stems and the hybrids of chokeberry and mountain ash (Burka Michurina). The grafts of chokeberry onto the crown of wild mountain ash develop into ornamental trees and bear early fruit of economic value.

The ornamental qualities of viburnum can be enhanced by crossing with large-flower varieties and its utility to man can be increased by using sweet fruit varieties rich in vitamin P and C. Widespread use of viburnum fruit by the population of the Urals and Siberia underscores the importance of this task.

Of interest are the big-fruit varieties of hawthorn, bearing fruit up to 3 cm. long....* The ornamental aspects of the hawthorn are because of the red-flower and double-flower varieties.

The ornamental values of the sea buckthorn have been noticed many times. Its slow growth in the podzolic soils of the Urals and frost susceptibility make necessary the breeding of vigorously growing arborescent plants from the frost-resistant Sayan ecotype, adjusted to local conditions. It is of interest to search for a monoecious sea buckthorn because the non-bearing male trees are of little ornamental value.

Sweetbriers are outstandingly ornamental and have a high vitamin content. Breeding of sweetbriers for high vitamin content is carried on by a number of institutions without regard to the ornamental properties of the plants. It is interesting to combine in a sweet brier vigorous growth, frost-resistance, large fruit, and ornamental properties. In this respect the double-flower varieties of the hedgerow rose as well as the northern double roses suitable for growing in open areas are of interest. Crossing these varieties with the yellow-flower or redleaf roses as well as with the high-vitamin sweetbrier of the E. M. Stepanova breeding can yield excellent plants combining beauty with exceptional usefulness of its fruit, rich in carotene, vitamin C, P-active flavones, and other valuable substances.

Also, of definite interest are gooseberries, e. g., tall-growing Chernyy Negus, Varshavskyy shtambovyy, as well as Kryzhovnik uzkoplodnyy and Seyanets altayskiy 55-44-1.

Of black currants, Doch'Altaya distinguished by strong bushes, is also of interest....*

While the gas resistance of the various tree species is known quite well, information concerning species that absorb large quantities of poisonous substances is very limited. There is practically no work extant comparing the rate of removal from the air of carbon monoxide and carcinogens by leaves of various species. The question of dust retention is in a similar state. Even though dust-resistant varieties are known, the capacity of their leaves to fix the dust and the consequences of it for man are not clear. It is unknown what is preferable: to plant varieties whose leaves do not fix injurious substances or, conversely, do fix such substances and make it possible later to remove them from the city along with the dropped leaves.

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* See previous footnote.

In 1962 the plant physiology laboratory of the ULTI began comparative studies of absorption of various poisons from the air by leaves of a number of tree species, and particularly by the ornamental fruit tree varieties previously discussed. It came to light that even among the apple varieties there are some that absorb 2-3 times as much as the ornamental apple tree. However, there too their effect of plants on the surrounding air does not solve the problem.

At present it is difficult to predict the period of time during which pollution of city air by various poisonous substances will continue. Indeed, an increase in the chemization of the national economy may increase pollution.

Developments in the technology of freeing industrial gases of poisonous substances will result in the fact that the absorptive activity of plants and their gas resistance will have no material significance. Of greater importance is the capacity of plants to exude through leaves, flowers, and bark volatile substances beneficial to man and capable of ionizing the air. The effect of plants on the chemical composition of the atmosphere is vastly more complicated than it was assumed to be. The utility of plants is ordinarily evaluated by their exudation of phytoncides, which are lethal to bacteria and also are insect repellents. However, exudation of phytoncides cannot be accepted as a measure of the utility of a plant species. Thus, one of the most phytoncidic species is the common laurel cherry, common chokeberry, and pin cherry. Their phytoncidity is due to the exudation by their leaves of a large quantity of hydrocyanic acid and the strong poison can hardly be called beneficial to man.

Most of the other phytoncides are poisonous both to bacteria and man. The more phytoncidic is a tree, the more dangerous it can be to man. Here should be pointed out various cases of allergy (hay fever) caused by various volatile plant substances absorbed by lung tissue or skin of man. The question of freeing the air of bacteria by phytoncides needs to be reviewed because of the toxicity of some disinfectants.

The giving off of volatile substances by trees and shrubs is noticed from the aroma during blooming of apple trees or sweetbrier, by the balsam aroma during the opening of poplar leaves or the essential oil scent during the frondescence of black currant bushes and others. However, the action of these volatile substances on lung tissue and the nervous system of man and the way in which it affects his well-being and health is little known in contemporary medicine....*

The effect of some plants is harmful, e.g., man is poisoned by the volatile exudation of azalea flowers, or the leaves of walnut (juglon acts narcotically or causes headache). On the other hand, the soothing action on the heart of inhaled camphor oil is well known.

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* See previous footnote.

The rapidity with which alkaloids (nicotine) or narcotics (hashish, opium) act when smoked is a good example of the brain's reaction to substances inhaled by the lungs.

The use of inhalation in lung disorders and the widespread use of essential oils (turpentine, mint and pine oils, anise drops, and the like) as popular remedies in treating colds are examples of the application of phytopharms. With each breath, in addition to oxygen and inert gases, we inhale many other substances which are absorbed by the organism and affect it in turn. Unfortunately, for the present, this refers predominantly to the toxic substances in the air and it should be the aim to replace them completely with beneficial substances. Until man can artificially make up the air composition to suit best his needs, the only means for changing the surrounding atmosphere is to enrich it with beneficial substances given off by plants.

Thus, the scientist is faced with a biological problem whose importance is magnified by its significance for the health and longevity of all mankind inhabiting the earth. Even in our northern latitudes we are subjected to the action of various plant exudations for half a year, i.e., for as long as there are leaves, and yet we know almost nothing about these substances nor how they affect our organism. It is quite possible that in its significance for mankind this factor (particularly if it be connected with life extension) does not yield in importance to the role of vitamins in our nutrition.

For the present, the verdant plantings are uniformly monotonous. In the Urals 75% of trees and shrubs in the cities are made up of poplar, maple, acacia, linden, and ash. But even for these few plants we have no data on the intensity and composition of their exuded essential oils, even though there are data on their phytoncidic action.

The matter of phytopharms is important for flowering plants growing on streets as well as kept indoors. Among the latter are frequently found those producing essential oils (lemon, gold raintree, coleus, geranium, arborvitae, and others) that affect us daily in a manner as yet unknown to us. Of considerable significance would be an increase in the air ionization, caused by some plants (Minkh, 1963), and an increase of ozone content of the air, as noticed, for example, with the coniferous species.

The use of beautiful plants beneficial to man's health in verdant plantings will signify a new era in ornamental tree growing.

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